POWER

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The Good of Giving

AN OLD lady on her knees in the garden picking a basket of pansies to send to the hospital, declined any credit for her kindness.

"I have to pick them anyway," she said; "if I don't, the plants will all dry up and go to seed."

I do not like to taint generous giving and free-hearted service with any suggestion of a selfish ulterior purpose or even effect, but it seemed to me that there was a text in the old lady's remark.

We all know the engineer who keeps the little that he knows bottled up so tightly that it shrinks for want of an occasional airing. He goes to the meetings of his society or association and picks up what he can from the side lines, but never contributes any of his own ideas or knowledge.

He seems to feel that if the other fellow knows as much as he does, the other fellow will be as big an engineer as he is and that he will suffer by comparison.

It is a matter of relativity with him. He expects to keep ahead by keeping the other fellow back.

Watch him dry up and go to seed.

The man who gives the best that there is in him to his associates in the association and elsewhere gets the most out of life and out of the association. He gets a new grip on things by telling them, gets the benefit of the knowledge that their discussion brings out, perhaps corrects some misconceptions. New ideas replace or amplify those that he has culled and he keeps on growing bigger and brighter.

And when a leader is wanted or somebody is looking for a man who knows things, he is the object of everybody's good will and the outstanding man for the position.

The same thing is true of firms and corporations. Many of them have dried up and gone to seed hugging a withering bunch of trade secrets and inside information, which usually their competitors know all about; while others, with the broader view, have come up and written themselves to the front with real contributions to the good of engineering in general and to that of their class of service in particular.

F. R. Low

Big Falls Development on Flambeau River

By L. B. BREEDLOVE

Three-unit plant, 9,900 kva. capacity, operating under net head of 52 ft. and average flow of 1,600 sec.-ft., to be tied in with four other hydro-electric developments of the Lake Superior District Power Co. Two 3,300-kva. units now installed. Interesting features are the dam and spillway construction and the special reinforcing of the scroll case by means of steel bands secured to the rim of the speed ring.

A HYDRO-ELECTRIC station having a number of unusual features has been constructed recently by The L. E. Myers Co., of Chicago, for the Lake Superior District Power Co., which serves a territory in northeastern Wisconsin and northwestern Michigan extending about seventy miles along the southerly shore of Lake Superior. This area contains the iron-mining district known as the Gogebic Range. Four hydro-electric stations on other rivers of that territory are now in operation, the new development making five in all. With the four older stations, one-half of the energy sold was produced hydro-electrically. With the addition of the new plant it is estimated 85 per cent will be produced by water power. The load in the mining district is especially favorable for the utilization of water power.

Storage Provides Average Flow of 1,600 Sec.-Ft.

The new dam and power house are about one-half mile below Big Falls and about ten miles northeast of the city of Ladysmith, Wis. Big Falls really consists of a series of three falls and rapids having a total head of about 40 ft. within a distance slightly over one-half mile. Stream-flow records for six years were available and showed a flow varying from 800 sec.-ft. as a minimum to 11,000 sec.-ft. as a maximum. The dam provides a storage volume of 70,000,000 cu.ft. This storage, when full, affects the stream surface for a distance of 5.5 miles above the dam. It is estimated that this storage volume, together with other storage to be developed later, will provide a 1,600-sec.-ft. flow over practically the entire year. The maximum head at the dam is 52 ft.

Over-all the dam is about 2,000 ft. long and is composed of five sections representing four general types of design, namely; two earth wing sections, concrete bulkhead section, combined power-house-dam section, and ogee-type concrete dam with tainter control gates in the spillway section. These types were chosen to take advantage of the natural conditions which allowed lowering of the construction cost.

Comparative estimates indicated that the dam could be shifted up or down stream within a range of perhaps 200 ft. without material change in cost. The location at the foot of the rapids was chosen in order that the power house and dam might be built as one structure, thus avoiding the use of steel penstocks 200 ft. long. The elimination of this penstock cost was sufficient to cover any additional cost of the dam at the lower site. The Power-house section was located just down stream from the rock bench east of the channel, as the site permitted excavation and construction of the power-house substructure to begin immediately with the initial construction operations in February, 1922. This location also permitted the construction work on the power

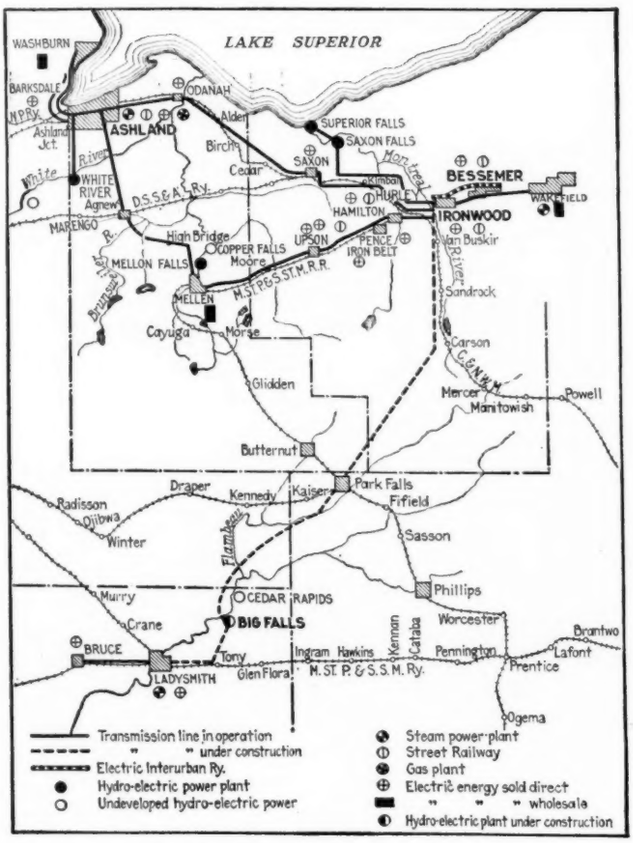
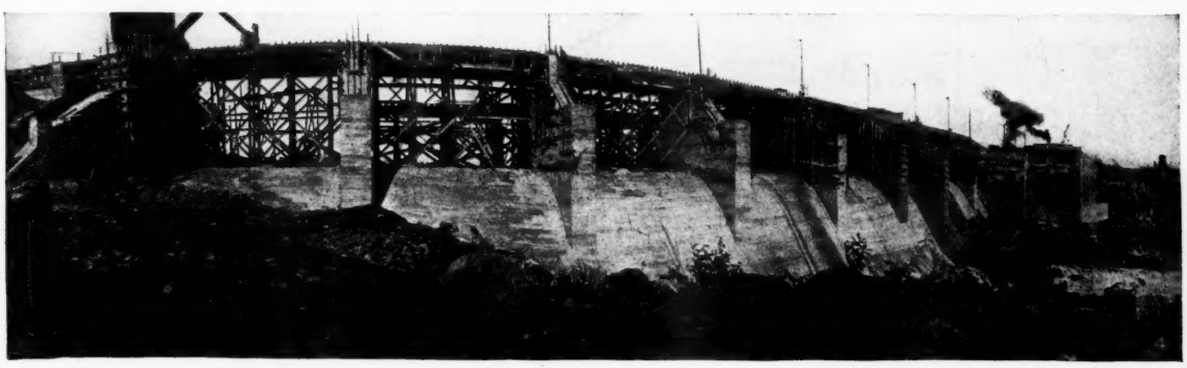


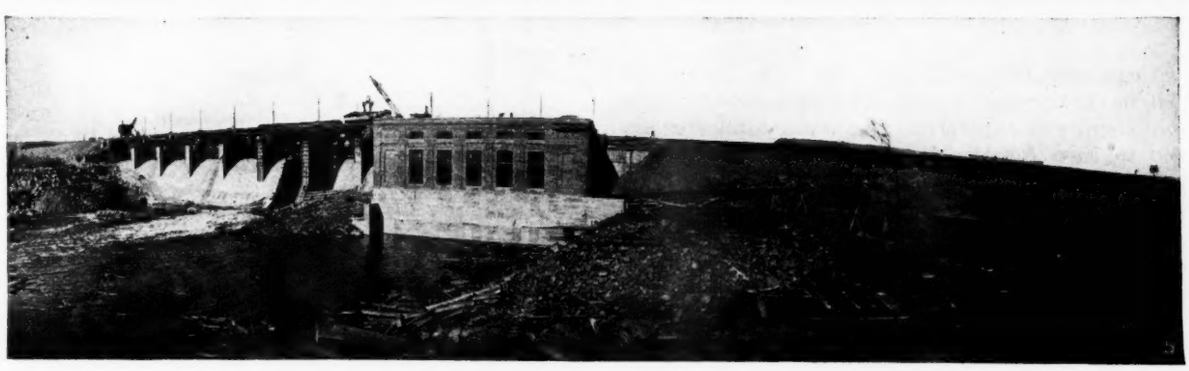
FIG. 1—TERRITORY SERVED BY LAKE SUPERIOR DISTRICT POWER CO.

house to proceed without any interruption from spring season floods for which no diversion channel could be provided.

Spillway Location Lowers Cost

Because of the short duration of flow records it was considered advisable to provide for flood capacity of 22,000 sec.-ft. or approximately twice the known maximum flood. The rock bench on the west side of the river was most suitable for the location of the cheapest spillway with minimum erosion possibilities at the toe. Its elevation was slightly too high to allow water to flow to it and away without reduction of flowage capacity. The boulder bed east of the river channel was suitable for spillway purposes, but was not of sufficient length. There was adequate length for a spillway having a water-flow depth of 12 ft., on the crest across the





FIGS. 2 TO 5—CONSTRUCTING DAM AND POWER HOUSE SIMULTANEOUSLY

Fig. 2—Early construction view, showing method of getting foundation and forms under way. The dam is two thousand feet long, composed of five sections, including four distinct types of design. An earth wing is on the east side. The concrete bulkhead section, together with power-house dam and spillway section, complete the dam. The latter section includes ogee-type concrete dam with tainter gate control. Fig. 3—Construction view, showing method of transporting materials. Well-graded glacial drift gravel with 25 to 50 per cent clay was available at each side for the wing sections. Concrete was easily produced by utilizing materials at hand. Fig. 4—Close-up view of uncompleted spillway section of the dam. This was composed of solid concrete, of ogee-type construction, and was placed on a boulder bed, east of the river at a considerable saving in cost. Fig. 5—Power house and dam at the time of closure. The first unit was placed in operation 11 months after beginning construction work. The arrangement of the power house and dam enabled both to be constructed at the same time without interference and thus save considerable time.

river channel west of the power house. The adoption of this depth of overflow in order to concentrate the spillway in a relatively short length at the main river channel permitted an earth dam to be constructed across the boulder bed at a considerable saving in cost.

As constructed, the spillway has a net length of 280 ft. for a depth of overflow of 12 ft., and is divided into eight openings, each 35 ft. long horizontally. These are controlled by tainter gates 13 ft. in depth. These gates are provided with two motor-operated hoists and also are equipped for hand operation. The hoists are mounted on a traveler frame running on 80-lb. rails laid on the spillway superstructure, while duplicates are provided to care for the disabling of a hoist during times of flood flow.

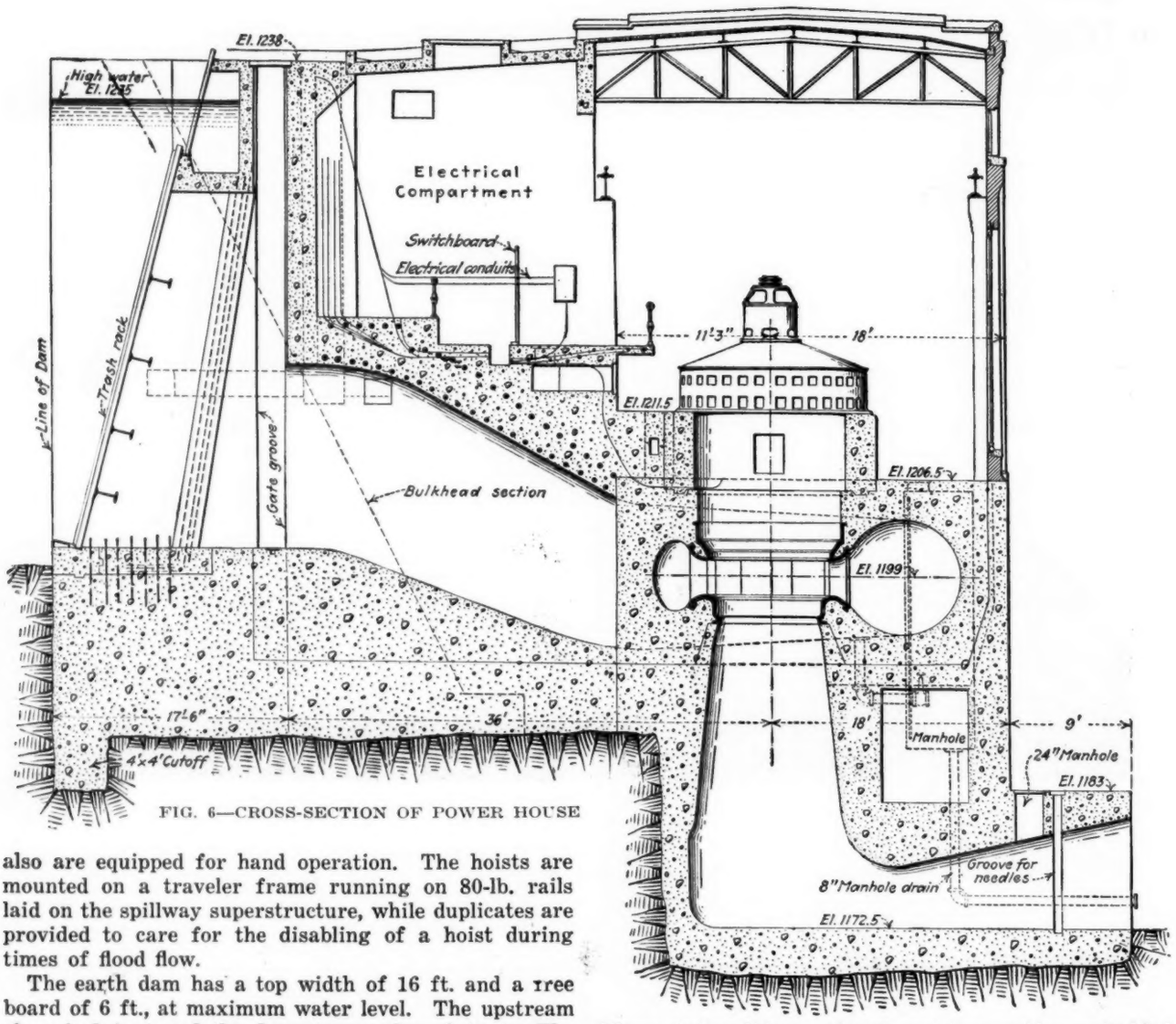


FIG. 6—CROSS-SECTION OF POWER HOUSE

The earth dam has a top width of 16 ft. and a free board of 6 ft., at maximum water level. The upstream slope is 3 to 1 and the downstream slope 2 to 1. The earth embankment on the east side of the river is provided with a concrete core wall about 3 ft. thick, built to approximately one-third the height of the dam where the dam is on exposed rock. Where built on earth footing, no sheeting or core wall in the dam is provided. Across the boulder bed east of the channel, where the earth dam has a maximum height of 36 ft. and sustains a depth of water of about 30 ft., a core wall was provided through the boulder bed. No core wall was provided for the remainder of the length of the east wing dam. The bulkhead section is of concrete construction with a 7-ft. top and a 32-ft. base set in a foundation channel excavated in the rock.

At the power-house section the dam and power house were built as one structure. The roof elevation of the power plant is approximately five feet above the top of the dam. The generator room is approximately 27 x 103 ft. The switch and bus compartment, 20 x 103 ft. in size, is between the buttresses of the headgate structure and generator room and directly over the penstock channels. Water for each unit is taken in through a square opening, 14 x 14 ft., with its center 27 ft. below the normal water elevation. Each opening is closed by structural-steel headgates with bronze bearing strips. These strips slide on planed cast-iron guides embedded in the concrete. The gates are hoisted by two screws 4½ in. in diameter, extending to the operating platform above and operated by two Coffin interconnected motor-operated screw hoists which are controlled from the switchboard. A 2 x 2-ft. sluice gate is provided as a bypass for each headgate to balance the pressure, when the gates are being opened, although the hoists are designed to operate with the gates under full head.

The penstocks are formed in concrete of ogee profile in changing from the 14x14-ft. square section at the entrance to the scroll case. The scroll cases are formed in concrete and are nearly circular in section throughout most of the length. They are reinforced by bands of 1-in. round steel with upset heads on the ends. These

heads are fitted into pockets cast in the rim of the speed ring and then wedged in the pocket to insure contact of the underside of the head with the metal of the speed ring.

The draft tubes were especially designed after tests made at the plant of the Wellman-Seaver Morgan Co., upon 2-in. models of several suggested designs. The 2-in. model of the adopted draft tube gave an efficiency of 68 per cent under test, this result being considered remarkable for so small a tube. The tube is a straight diverging cone for a distance of 16 ft., at which point it enters an elbow spreading out rapidly in width, but with a small vertical height of throat.

The tops of the trash racks are about three feet below normal water level. At this elevation a seat is provided for needles to close the remaining opening from the top of the trash racks to the operating platform. Behind the needles is a trash trough discharging through a hole behind the first tainter gate. These needles can be withdrawn singly or in groups as desired to pass trash into the trough behind them, in which water will be maintained at a level lower than that of the pond.

Three Units To Be Installed Ultimately

Two General Electric 2,300-volt 60-cycle three-phase generator units of 3,300-kva. capacity driven by Wellman-Seaver-Morgan vertical single-runner turbines developing 4000 b.hp. at a net head of 52 ft., are installed. A third unit is to be put in at a later date.

Exciters are of the direct-connected type. The generator is mounted on a concrete pedestal about five feet high provided with a doorway for entering the turbine chamber underneath the generator and with special holes for increased generator ventilation. These units are controlled by Woodward governors with motor-driven oil pump and motor-driven flyballs. The pump motors are driven from the station power transformers while the flyball motors are each driven through two 200-watt potential transformers, energized from the generator leads and functioning in every respect as a belt. The servo-motor is on the generator floor and acts through a hole in the pedestal on a crank at the top of the gate shaft inside the turbine pit.

The governor actuators are on the switchboard level as are also the oil pumps for hand operation. The platform on top of the generator is located at the level of the switchboard floor and connected to the floor by a walkway. This brings the governor actuator, the governor hand operation, the inspection platform for the generator thrust bearing, exciter brushes and collector rings all at the same level, so that one attendant can observe, maintain and operate this equipment. The only operation that must be carried out at any level other than that of the switchboard floor is the greasing of the turbine in the pit underneath the generator. For this purpose "Dot" lubricating fittings with grease gun have been provided instead of the customary grease cups.

All leads from the generator units are carried in conduits installed in the concrete to the electrical control room located between the head gates and the generator room. The 2,300-volt oil switches, station power and light transformers, and busbars are installed in compartments. The high-tension transformers and switching apparatus are located with a high-tension outdoor switching structural support built on a concrete platform adjacent to the power house. The 2,300-volt leads from the busbars to the high-tension tower are carried on overhead supports because of the new and unsettled rock fill between the power house and the tower. The high-tension equipment is installed to operate at 88,000 volts. Two three-phase transmission circuits carried on steel towers are now being constructed to connect this plant with the present transmission system of the Lake Superior District Power Co. at the City of Ironwood, Wis., a distance of 88 miles.

On Jan. 15, 1923, the first unit was placed in operation, eleven months after work was started at the site. The engineering and construction were completed by the L. E. Myers Co. organization, with L. F. Harza as consulting engineer in direct supervision of design.

Starting the Producer Gas Engine

By H. Weiland Los

Starting a producer gas engine of the suction type is quite simple when the plant is in good mechanical condition and a gas of good quality is produced systematically.

One should not attempt to start the engine when the producer is entirely charged with fuel and more or less choked up by ashes and clinkers. Feeding fuel to the producer should be discontinued during the last two or three hours the engine is in operation, in order to decrease the height of the fuel bed. This will enable the operator to remove the ashes and clinkers quickly and easily, giving him a chance to add fresh fuel when fanning the producer.

There is another good method of starting a producer. Empty and clear the producer entirely and remove all refuse between the grate bars. Now cover the grate through the firedoor with a few shovelfuls of live coal and blow up until the fire appears white, which may be observed through the mica-covered peep hole in the producer cover. Add some buckets of fresh coal and wait until the gas ignites readily at the test cock and burns with a big flame, after which the engine may be started.

Feeding the fresh coal to the producer before the charge of live coal burns briskly will cause the temperature of the fire to drop considerably, thereby reducing the percentage of CO as produced by chemical reduction to a minimum. In such a case it is advisable to stop blowing, draw the fire and start making gas again, otherwise the whole mass of fuel will ignite gradually, irrespective of the quantity of fuel fed to the producer, causing ignition of the combustible gases on top of the fuel bed.

The condition of the valves and piston of the engine is very important, as the compression is reduced before starting the engine and the first explosions always are comparatively weak. Especially, the stem of the exhaust valve should have a minimum clearance in its bushing in order to prevent excessive leakage of the valve, which may cause failure when starting the engine. If there is too much clearance, the valve is not properly guided and the seat will wear to an oval. Grinding the valve will produce the same effect and generally makes matters worse.

Clear the valve and seat thoroughly after grinding and mark the seat with a few chalk lines, say six or eight. The valve is tight when it is possible to grind these marks entirely away.

In order to offer the least resistance, the passages should be kept practically free of tar, but this is easy compared with cleaning a steam boiler.

The Determination of Boiler Efficiency

By HENRY B. JONES
Station Engineer, Susquehanna Collieries Company

IN THIS discussion the term "boiler" will be used to designate the combined boiler and furnace, together with such auxiliaries, economizers and superheaters for example as may be included at the option of the engineer directing the tests.

The efficiency of a boiler is obtained by dividing the output by the input. Both output and input are necessarily based on measurements, and are therefore, like all measured quantities, more or less in error. If we assume for the moment that the input (denominator) is correct, the percentage error in the efficiency will be the same as the percentage error in the output (numerator). If the output is 2 per cent high, the efficiency will be 2 per cent high.[1]

If the output is 3 per cent low, the efficiency will be 3 per cent low. On the other hand, if the output is assumed to be exact while the input is in error, a given percentage error will produce practically the same error (though in the opposite direction) in the efficiency. This statement is extremely close to the facts for variations of not more than 3 or 4 per cent. For example, if the output is correct but the input 3 per cent high, the computed efficiency will be $100 \times (100 \div 103) = 97.09$ per cent of the correct value, or in other words, 2.91 per cent low. It may then be taken as practically true for small variations that a given percentage error in either output or input makes the same percentage error in the computed efficiency.

OF THE thousands of boiler tests made every year in this country a large proportion are of little value, because conducted in utter disregard of the scientific principles that underlie all experimental work. It is, of course, impossible for any experimental work to be exact in an absolute sense. The important thing is to know what errors may be expected in the various measurements in order to conduct the test in an intelligent manner. In this article Mr. Jones makes a careful scientific analysis of the errors that arise in determining boiler efficiency.

The errors in output and input may add up or partly neutralize each other. For example, if the output is 2 per cent high and the input 3 per cent low, the computed efficiency will be 5 per cent (2 + 3) high, while if the output is 2 per cent high and the input 3 per cent high, the computed efficiency will be 1 per cent low.

The foregoing statements are in accord with the general principle that when numbers are multiplied or divided, a given (small) percentage change in any of the numbers produces the same percentage change in the answer.

Now, for any given test there is in the final result a certain maximum percentage of error that cannot be exceeded without defeating the purpose of the investigation. If this limit is, say, 4 per cent of the true value and it is known that the possible error in input is 3 per cent and in output is 2 per cent, there is some chance of the two errors' both being simultaneously at the maximum and in such directions as to give a total error of 5 per cent, which is greater than the allowable limit. The accuracy with which it is necessary to find the output and input must be established with this possibility in view, and apparatus for their determination selected accordingly.

In a boiler test both output and input are expressed in B.t.u. The output is the energy added to the water during its passage through the boiler and is determined by measuring the quantity of water passing in a given time. This measurement may be made either as the water enters the boiler or as it leaves in the form of steam. In addition to determining the quantity of water, it is necessary to ascertain its total heat as it enters and the total heat of the steam as it leaves the boiler. The importance to the test of the correct measurement of the water evaporated is so great as to render it advisable, where it is at all possible, to measure it in more than one way, requiring that the several methods check closely as to result. Moreover, all possible precautions must be taken to see that the quantity and heat condition of the water stored in the boiler is the same at the end of the test as at the beginning. Where the water is to be measured before entering the boiler, weighing is preferable to volumetric measurements. Scales should be carefully tested with standard weights, and tanks should be arranged to discharge quickly into the reservoir from which the feed pump gets its supply. Errors to be especially guarded against are the running over of weigh tanks, or suction tanks, and the running of water through a weigh tank without having its discharge valve closed, and mistakes in measuring the depth of the water in the pump's suction reservoir at the ends of the test and hourly periods.

If volumetric measurement must be resorted to, the temperature must be noted and the density of the water taken into account in calculating the weights. A highly intelligent man should be assigned to the task of water measurement, one of the technical staff if possible, as this man must recognize the importance of accuracy in his work and must report immediately to the engineer in charge the occurrence of any error, such as running over a tank. Except with precision meters, dependence upon meters for measuring the water is likely to introduce undesirable errors even though the meters be carefully calibrated in position.

For some work not requiring extreme accuracy the steam-flow meter may be used, care being taken to get a reliable instrument. Measurement of the steam has the advantage that less error is then introduced by leaks of the boiler and its fittings. Error is introduced, however, if the safety valves lift, and as steam flow cannot be measured as accurately as water flow, the efficiency calculation should be based on water flow ex-

[1] That is, 2 per cent *of the correct value*, so that if the true efficiency were 60 per cent, the computed efficiency would be 60 + 2 per cent of 60 = 60 + 1.2 = 61.2 per cent.

cept where approximate results will be satisfactory. With the quantity of water fed to the boiler determined with acceptable accuracy, assurance must be had that all this water actually entered the boiler and was all actually evaporated and delivered by the boiler as steam. If some of it was not so delivered, that part must be determined as must the quantity of heat contained therein. If the piping from the point of measurement leads only to the boiler under test, with no branches entering or leaving, and if this pipe is so located as to be at all times subject to observation and shows no leaks whatever, it may be safely assumed that the water measured entered the boiler. If there are branch connections to this piping, these should be disconnected and the necessary outlets plugged. In this way all possibility is eliminated of part of the measured water finding its way elsewhere than to the test boiler, and of any unmeasured water getting into the test boiler.

If blowoff valves are blanked off or their piping disconnected and care is used to prevent safety valves lifting during the progress of the test, leaks present the only possible way for water fed to the boiler to leave it except by the steam line. A leakage test with either steam or hydrostatic pressure should be made to insure that the loss by leaks is too small to affect the accuracy of the test.

In so far as the lifting of safety valves during a test is concerned, it may be said that it is best to avoid it in all cases, but that if the valve which lifts emits steam of the same quality as that delivered by the boiler to the connecting mains, no inaccuracy is introduced other than such as may be incurred by the resulting wide fluctuation in the load. If, however, the boiler has a superheater that is being included in the test and the safety valve which lifts is connected directly to a steam drum, an error is introduced whose magnitude may be serious. While this error may be calculated from the rating of the valve and the duration of its discharge, it is obviously much better to avoid it altogether.

Water Level Should Not Change

When depending upon measurements made before the water enters the boiler, it is essential that the quantity of water in the boiler be the same at the end as at the start of the test. To make certain of this it is customary to tie a string around the gage glass at the water level at the start of the test and then either see that the level is the same at the end or note the difference and make a suitable correction. Every effort should be made to avoid the necessity of such a correction.

It has been found in certain types of boilers, of which the Stirling type is an example, that the water level in the rear drum is not the same as in the middle drum to which the water column is ordinarily connected, being lower at all times by an amount dependent upon the rapidity of the circulation. As this discrepancy can easily introduce serious error on a short test, it should be guarded against by having the boiler steaming at exactly the same rate at the end as at the start of the test. A better way to take care of this is to arrange water glasses in a specially connected column of suitable length to permit of this level being observed at all times during the test.

Water columns and glasses should not be blown for at least an hour before the start or end of the test, as doing so may, by changing the temperature of the water in the column or glass, introduce an error caused by the corresponding change in volume.

The heat put into each pound of steam is the difference between the total heat of the steam and the total heat of the feed water. To determine the total heat per pound of feed water, it is only necessary to measure its temperature. This should be done as close to the boiler as possible. The thermometers used should be carefully calibrated and the best practice in temperature measurement followed.

Determining the Heat in the Steam

The total heat per pound of steam delivered is considerably more difficult to obtain, and the two conditions of saturated and superheated steam require different methods. In the case of saturated steam a calorimeter must be used to determine the percentage of moisture. Within certain small limits the throttling calorimeter may be regarded as satisfactorily accurate. Beyond these limits the moisture content cannot be ascertained with acceptable precision, and this will in such cases be the factor limiting the accuracy of the determination of the output, and hence of the efficiency.

If a superheater is included in the test, the temperature of the steam is measured. When the superheater has two outlets, the temperature must be measured at each, and the two should check within five or ten degrees.

The pressure at which evaporation takes place should be determined with accurate bourdon gages connected to the steam space of the boiler, and should be the same at both ends of the test and as nearly uniform as possible throughout the test.

The heat input of the boiler is the product of the weight of fuel by its heating value per pound. It is important that the amount of heat energy in the furnace be practically the same at the end of the test as at the beginning. In the case of fuels burned in suspension, the difference in this quantity at the two times can hardly be large enough to affect the results materially, provided the fire has been in operation for some time prior to the start of the test, but in the case of fuel burned on grates this matter must be most carefully considered.

Weight Measurement Best for Fuel Oil

Fuel oil can be weighed in much the same manner as the water is weighed, and this is the most satisfactory method where extreme accuracy is sought. When the requirements are less rigid, volumetric measurement may be resorted to or displacement meters employed. If meters are used, they should be carefully calibrated in position and for the rate of flow to be employed during the test. Frequently, tank measurements can be used, and where the tank is small enough to give a fairly large difference in level between readings very good results can be obtained. The temperature must be noted when this method is employed. In depending upon tank measurements, care must be taken to guard against leaks into or out of the tank, and no new supply of oil may be added to the tank during the test. Tank measurements are especially valuable as a check upon meter readings though they should not be relied upon as a calibration of the meter, for which purpose weights should be taken.

Gas cannot be readily weighed, and direct volumetric determination of the quantity used is seldom possible, though where a gas holder of sufficient capacity is avail-

able, it offers the most accurate means of determining the quantity of gas used. General practice among large users of gas is to depend upon orifice meters for those measurements where the highest degree of accuracy is required.

Measuring Refuse Fuels

Wood refuse or "hogged fuel" and bagasse are most difficult to handle under test conditions, and their high moisture content requires that unusual care be taken with the samples to prevent loss of moisture in handling. With these fuels all the fuel fired should be weighed (no dependence whatever being placed upon volumetric methods. Where the feed of the fuel to the fire is continuous, as by gravity from a conveyor, the weighed fuel must be re-delivered to the conveyor so as to feed the furnace in a normal manner and not intermittently.

Lignite and coke breeze may be treated in the same general manner as coal, hereinafter discussed, but extra precautions must be taken in sampling the former to prevent loss of moisture.

In testing pulverized-fuel plants the fuel must be weighed if accurate results are desired. In installations where each boiler has two entirely separate dust bins, it is usually not difficult to arrange to weigh enough pulverized coal into an empty bin to run the entire test. As the test draws to a close, it will be necessary to watch the feed, and at the first sign of irregularity as a result of the bin getting low the test must be stopped, the feed shifted to the other bin and the amount of dust remaining in the test bin weighed and deducted from the amount put into the empty bin prior to the test.

Where but one bin is available, it is suggested that it be filled as full as possible at the start of the test and at the end refilled to the same point as closely as may be determined. In such cases the test should be of such length that any discrepancy in the measurement of the coal that could possibly occur from this cause would result in an error in the calculation of efficiency well within the required limit.

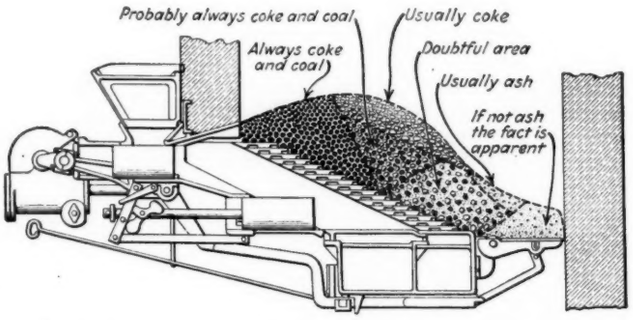
How to Measure Pulverized Coal

Methods of weighing pulverized coal have been developed to eliminate the loss due to dusting. These consist, in general, of a tank mounted on scales, with canvas connections to the supply and to the bin into which the coal is being weighed. Gates are provided at top and bottom. This method has been found satisfactory, though care must be exercised to guard against leaks at the shutoff valves. The sampling of pulverized coal is a simple matter, as the crushing and mixing have been most thoroughly attended to in the course of its preparation, but care must be taken to avoid alteration of the moisture content of the samples.

If care is not used in handling, serious inaccuracies may be introduced through dusting. Volumetric measurements must not be relied upon, as the density of pulverized coal is not constant. A bin with a capacity of a thousand cubic feet and a depth of ten feet will frequently settle a foot or more in forty-eight hours. The extent of this settling is dependent upon such factors as fineness, moisture content and aëration.

Coal should be weighed, although with the small steam sizes of anthracite volumetric measurements may be relied upon for tests where an error of 1½ or 2 per cent in the determination of the input is permissible.

Little need be said as to methods of handling and sampling coal, but in common with other grate-fired fuels such as wood refuse, bagasse and lignite, consideration must be given to the quantity of heat energy on the grate at the beginning and end of the test. This matter is most easily handled in the case of hand-fired grates and chain-grate stokers where the fuel bed is relatively uniform and the volume of matter on the grates relatively small. In the case of underfeed stokers the "judging" of the fire is much more difficult, and it is easy for the most experienced test engineers to make errors of considerable magnitude in this connection. The usual practice is to make the test of considerable length so as to minimize the effect of this error. As a rule, however, twenty-four hours is regarded as sufficient for this purpose, whereas it often



CROSS-SECTION OF FUEL BED ON UNDERFEED STOKER

This diagram shows a more or less arbitrary division of the fuel bed into zones. The actual division should be agreed upon by the engineers in charge of the test.

happens that it is far too short, particularly if the test be made at low rating and on a very large boiler. The length of the test might better be considered in terms of the quantity of fuel to be burned than in terms of time. With an underfeed stoker the test should be of such length that the maximum possible error from misjudging the fire will not affect the accuracy of the measurement of the heat-energy input by an amount greater than the limit decided upon as necessary for the test at hand.

Factors Determining Minimum Length of Test

Consider the cross-sectional outline of a fuel bed on an under-feed stoker as shown in the accompanying diagram. Such an outline should be prepared prior to the test, to conform to what experience has shown to be usual for the given furnace and the rating at which the test is to be made. The engineers responsible for the test should then confer upon some such division of the area as shown in the figure, and an agreement should be reached as to the probable size of that area the condition of which is not apparent from observation of the surface of the fuel bed. In the figure this area is marked "doubtful area."

If the usual care is taken to have the bed of the same size and shape at the end of the test as at the beginning, it may safely be assumed that the amount of heat energy in the other parts of the fuel bed is the same at the two times, for the specific heats of the various substances present are very nearly alike. Obviously, then, the maximum error in judging the fire would be encountered if the doubtful area was all coal at one end of the test and all clinker at the other end. As this disparity could hardly exist without being apparent to an experi-

enced engineer, some reduction in the length of the test can be safely made by agreeing on the greatest percentage of this area that could be ash at one end of the test and coke at the other without such change in condition being apparent.

Computation for Length of Test

As an example[2] suppose that it is desired to run a test on a 15,000-sq.ft. boiler at 100 per cent of rating, and that an efficiency of 75 per cent is expected. It is desired that the error in efficiency be kept below 1.5 per cent (that is that the "flat" difference between the true percentage efficiency and the computed percentage efficiency be below 1.5). The furnace width is 27 ft. 6 in. The doubtful area is 5 sq.ft. and it is agreed that this area might be 80 per cent coke or 80 per cent clinker without the difference being apparent. The fuel runs 13,000 B.t.u. per pound. Then the volume that may be coke or clinker is $5.0 \times 27.5 \times 0.80 = 110$ cu.ft.

The weight of this volume of coke, figured at 32 lb. per cu.ft., is $110 \times 32 = 3{,}520$ lb. If the coke is assumed to have a heating value of 12,000 B.t.u. per pound, the equivalent weight of coal is $\frac{3{,}520 \times 12{,}000}{2{,}000 \times 13{,}000} = 1.63$ tons. An error of 1½ "points" in an efficiency of 75 per cent is equivalent to a percentage variation in input of approximately $100 \times \frac{1.5}{75} = 2$ per cent. In other words, 1.63 tons of coal must not be more than 2 per cent of the total coal fired during the test. It follows that the minimum weight of coal fired must be $1.63 \div 0.02 = 81.5$ tons.

It merely remains to figure how long the test must last to burn this amount of coal. Normal rating is the evaporation of 3.45 lb. of water from and at 212 deg. (requiring 970 B.t.u. per pound) per square foot of heating surface per hour. The total heat output per hour at rating will be $3.45 \times 970 \times 15{,}000 = 50{,}100{,}000$ B.t.u., and the heat output per ton of coal fired $0.75 \times 13{,}000 \times 2{,}000 = 19{,}500{,}000$ B.t.u. The weight of coal burned per hour will then be $50{,}100{,}000 \div 19{,}500{,}000 = 2.57$ tons, and the time required to burn 81.5 tons will be $81.5 \div 2.57 = 31.7$ hours. This, then, is the minimum length of test needed to insure that the error in efficiency due to the difference between the starting and stopping condition of the fire shall not exceed 1½ "points."

Formula for Figuring Length of Test

The computation has been carried out item by item to show the principles upon which it is based. In practice the work may be shortened by using the following formula, which is based on the same constants for coke, namely, 32 lb. per cu.ft. and 12,000 B.t.u. per lb.:

$$\text{Minimum duration of test} = \frac{114 \times \text{width of furnace} \times \text{doubtful area} \times \text{doubtful fraction} \times (\text{efficiency})^2}{\text{sq.ft. of heating surface} \times \text{per cent rating} \times \text{permissible points error in efficiency}}$$

In this formula the efficiency is expressed as a percentage. Substituting the data of the problem in this formula we get:

$$\text{Minimum duration of test} = \frac{114 \times 27.5 \times 5.0 \times 0.8 \times (75)^2}{15{,}000 \times 100 \times 1.5} = 31.4 \text{ hr.}$$

[2]The computations in this problem are carried through in round numbers because extreme accuracy is meaningless where several of the factors are merely rough estimates.

Attention is directed to the fact that the foregoing formula assumes that all the error lies in this one item of the input. There are other sources of error in this determination than that due to misjudging the condition of the fuel bed. The relative magnitude of these may be agreed upon, and for purposes of determining the length of the tests the allowable error due to this particular cause, may be made correspondingly smaller. This allowance should be made with care.

As the quantity of heat in the setting should be the same at the start and finish, the test should not be started until after the boiler has operated at very nearly the same rating as is to be maintained on the test for a period varying from 24 hr. for a 2,000-sq.ft. boiler, to seven days for a 20,000-sq.ft. boiler.

Evaporative tests are usually expensive if made accurately and worthless if made inaccurately. Therefore the test or series of tests should be preceded by a careful estimate of the probable cost; the required accuracy should be determined upon, the various sources of error considered, and the funds available expended so as to effect the greatest over-all accuracy. If such consideration of the circumstances renders it plain that the necessary accuracy cannot be obtained within the limit of the available funds, the work should not be undertaken.

Fuel Sampling Important

The matter of errors in fuel analyses will not be examined into deeply. It should be said, however, that the analyses should be made by a competent chemist, who will under favorable circumstances get results accurate to within 0.3 per cent. In so far as the test engineer is concerned, the important point in this connection is the sampling, which must be so done as to get a representative sample of the fuel burned and so as to preserve its condition without change.

The energy input to a boiler includes certain other items besides the energy contained in the fuel. There is, however, no general agreement among engineers as to the proper method of allowing for the electrical energy or steam used by the auxiliaries, such as feed pumps, forced-draft fans, stokers, clinker grinders, soot blowers, oil heaters, etc. In the case of soot blowers, of course, where live steam is used and none of the heat is used for feed-water heating, it is correct to subtract the steam used from the gross steam produced by the boiler. But as far as the other auxiliaries are concerned, practice varies all the way from deducting the full weight of steam used by steam-driven auxiliaries, or used in the production of electricity for electrically-driven auxiliaries on the one hand to the charging of the B.t.u. equivalent of the net work done on the other hand. Good arguments can be advanced for both methods. In view of this state of affairs it is perhaps best to report the boiler efficiency as though the auxiliary power were free, and then to append the statement that the auxiliaries require so many pounds of steam and so many kilowatts for their operation.

In conclusion, attention is directed to the fact that the efficiency of a steam boiler may be determined without knowledge of flue-gas temperature or analysis, and with no other knowledge of the fuel than the B.t.u. per pound. The other data usually taken on such a test are for the determination and analysis of the losses. Although a complete and accurate determination of these losses serves as an excellent check on the determination of efficiency, it is not essential.

Generator Voltage Regulators—Direct-Current Type

Operation of a Regulator for Automatically Controlling the Voltage of Direct-Current Generators—How to Put Machines into Service and Take Them Out When Using This Device

By J. H. ASHBAUGH
Engineer, Regulator Engineering Department. Westinghouse Electric and Manufacturing Company

DIRECT-CURRENT generators offer such ease of regulation that the need for regulators is small. The fact that a compound winding can be used, the generated voltage remaining practically constant from no load to full load, makes the demand for regulators somewhat limited. Likewise the difficulty of making a satisfactory voltage regulator is small.

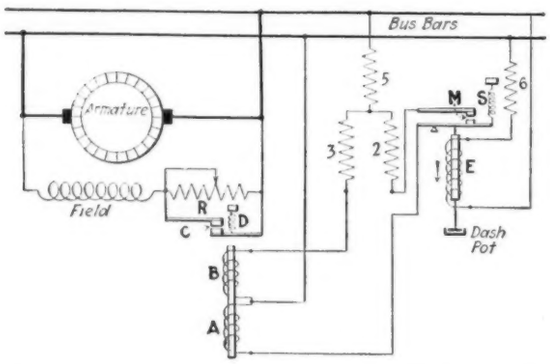


FIG. 1—SCHEMATIC DIAGRAM OF AN ELEMENTARY VOLTAGE REGULATOR

Due largely to the simplicity of the problem and the fact that direct current was more common than alternating, the direct-current regulator was the first type designed. Thomas A. Edison built the first regulator, but it remained for Allen A. Tirrill to make it a successful commercial product. The problem of regulating the voltage of a direct-current generator by a relay vibrating across the main field rheostat—that is, alternately short-circuiting and connecting the rheostat in circuit—is relatively simple, since the time required to change the field strength is almost negligible.

Fig. 1 is a schematic diagram showing the elementary regulator. The main control element *E* is energized from the busbars and pulls down against the tension of the spring *S*. The secondary relay *AB*, which is commonly known as the rheostat shunting relay, is wound differentially; that is, two windings constitute the circuit, one being constantly energized and the other energized only when the main contacts *M* are closed. When both windings are energized, they neutralize each other and contacts *C* are closed by the action of a spring *D*. The use of a differential relay makes the response quicker and relieves the duty imposed on the main contacts.

If the voltage rises in value, this will cause an increase in current in the main coil *E*, which will cause it to pull down and open the main contacts *M*, which de-energizes winding *A* of the relay. Winding *B* is permanently energized and opposes winding *A*, therefore when winding *A* is opened, the pull exerted by coil *B* will open contacts *C*, thus removing the short-circuit on the rheostat *R*. As a result the field current will be decreased and the bus voltage reduced. When this voltage lowers sufficiently, the pull of coil *E* is overcome and spring *S* closes contacts *M*. This energizes winding *A*, which neutralizes the flux of winding *B* and spring *D* closes the contact *C*, thus short-circuiting rheostat *R*. The field current immediately increasing, causes a rise in bus voltage. The sequence is then repeated. The action is quite rapid and the change in voltage cannot be noticed on a meter. The main contacts *M* appear to be stationary, although they actually move. A dashpot is used to damp out the natural vibration of the lever system.

If the machine is small, the main contacts of the regulator can be used to short-circuit the field rheostat; that is, the secondary relay is omitted and contacts *M* are connected directly to rheostat *R*. However, the work that the main contacts will do is limited; when the field current is large, it is necessary to interpose a secondary relay which short-circuits the field rheostat.

The field of a moderate-sized direct-current machine will respond to the vibrations of an ordinary type of relay so quickly that a perceptible flicker will be noticed on any lamps that are connected to the machine being regulated. The reason for this is that the bus voltage must, of necessity, change before the main contacts can operate. This objectionable feature has been overcome, and a regulator is available that has a high rate of vibration. This regulator is so designed that if the main contacts open or close, a force is set up in the main control coil which opposes the action of the

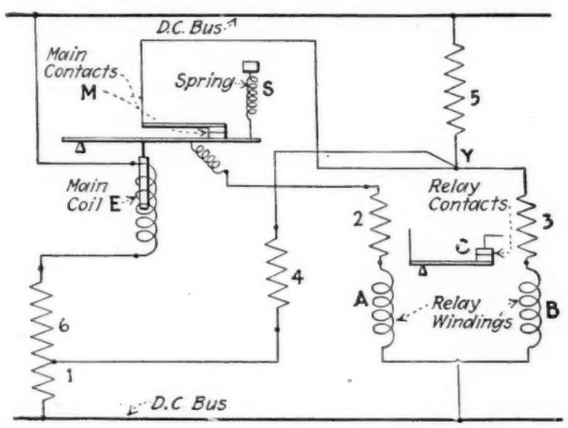


FIG. 2—SCHEMATIC DIAGRAM OF A VOLTAGE REGULATOR THAT HAS A HIGH RATE OF VIBRATION

contact. Thus the vibration does not depend on a change in bus voltage, but the contact is forced to vibrate. The bus voltage merely determines the time that the contacts are closed. This is accomplished by connecting a resistance between a portion of the external resistor in series with the main control coil and

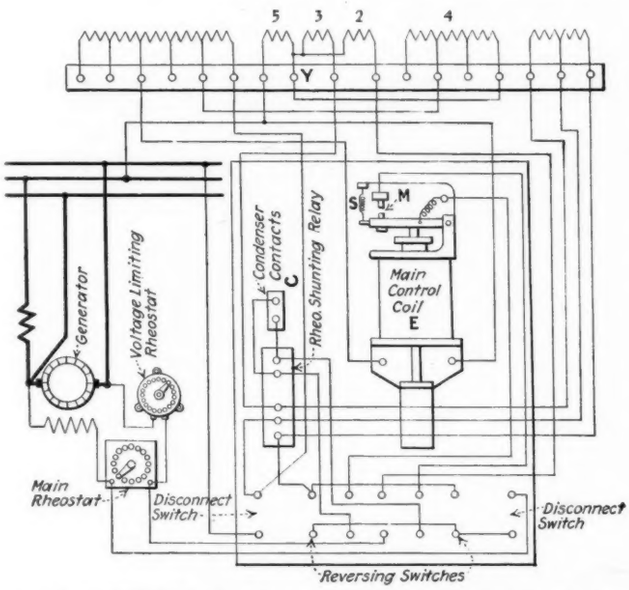


FIG. 3—WIRING DIAGRAM OF A HIGH-SPEED DIRECT-CURRENT VOLTAGE REGULATOR

the relays, as shown in the schematic diagram of Fig. 2.

Analyzing the action of this regulator, it is seen that winding *B* is constantly energized while winding *A* is alternately energized and de-energized by the action of main contacts *M*. A tap is brought out of the external resistance in series with coil *E* and is connected through resistance 4 to terminal *Y*. Thus when contacts *M* are open, resistances 3 and 1 are in parallel. But when the main contacts close, resistances 1, 2 and 3 are in parallel, which reduces the voltage drop of resistance 1, and more current will flow through coil *E*, which tends to open the contacts. As soon as these contacts open, only resistances 1 and 3 are in parallel, which increases the voltage drop, thereby reducing the current in coil *E* and tending to close the contacts. From the foregoing explanation it is seen that the result of resistance 4 is to produce a rapid rate of vibration, and the regulator does not depend for its vibration upon a change in bus voltage. Fig. 3 is the wiring diagram and Fig. 4 is a photograph of a high-speed regulator. This regulator was particularly applicable to installations where an exceedingly steady voltage is desired, such as film developing, etc., as it entirely eliminates any flicker on the lights and brings the voltage to normal quickly upon a change in load.

In placing a direct-current regulator in service, the generator should first be built up to normal voltage, care being exercised not to exceed this value. If the voltage exceeds normal, it should be reduced to residual and built up again. It is essential not to exceed normal voltage because the hysteresis in the iron will affect the field current required. The voltage should then be brought down to 65 per cent of normal; that is, reduce the voltage 35 per cent. Care should be taken not to reduce it below this value. The rheostat should then be marked in this position. This is the position that the rheostat should be in when the regulator is in operation.

When the machine is running at normal speed no load, the regulator is cut in on this machine by closing all switches to the rheostat shunting relays, after which the rheostat is turned to the marked position. The dashpot should then be adjusted to give the maximum rate of vibration. If two or more compound-wound generators are operated in parallel from one regulator, they should be adjusted so as not to exceed flat compounding. It is preferable to give them a slightly drooping characteristic.

When the field current of the machine exceeds a capacity of a single relay, the rheostat is divided into two or more sections, each section being connected to a pair of relay contacts. Thus, if a large machine were to be controlled, there would be a group of relays all operated by the main contacts.

A condenser is connected across the contacts of the rheostat shunting relay to absorb the discharge when the contacts open. If the current is small, two condensers may be connected in series, the next combination being one condenser and for heavier field currents

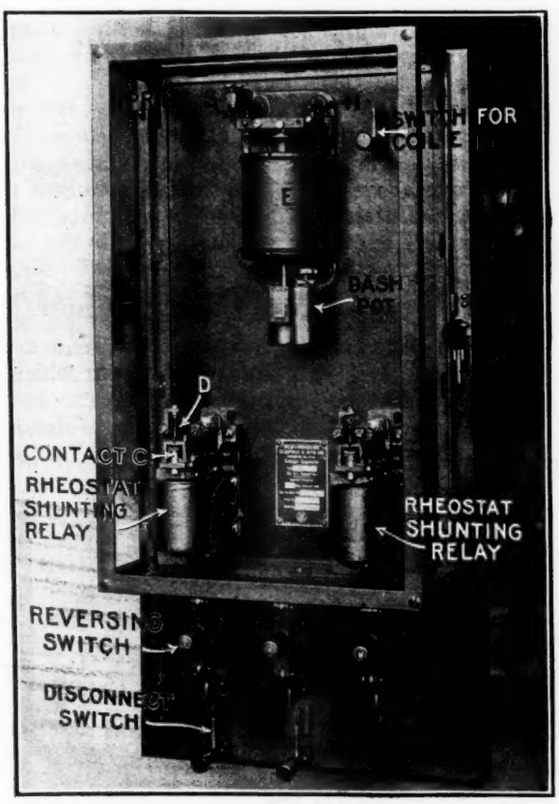


FIG. 4—HIGH-SPEED DIRECT-CURRENT VOLTAGE REGULATOR HAVING TWO RELAYS

two condensers connected in parallel. It is always desirable to operate with a minimum amount of condenser capacity, and it is necssary to have only enough condenser capacity to prevent the relays from flashing over at the maximum voltage. When too much capacity is used, the contacts of the relays will build up and finally weld together. This welding is due to the stored energy in the condenser dissipating itself at the contact surfaces when the latter close.

If a single direct-current machine is operated with a regulator, it is not necessary to take the regulator out of service before shutting down the machine. The regulator can be left connected to the machine at all times and the unit started and stopped in the usual manner, the rheostat being left in the marked position. When two or more machines are operated from a single regulator, it is desirable to have two field rheostats—one main rheostat and the other the voltage-limiting or equalizing rheostat, these rheostats being connected in series. This second rheostat makes it more convenient in operating, the rheostat shunting relays operating across the main rheostat.

If one machine is to be shut down, the voltage-limiting rheostat should be slowly cut in, reducing the load to zero. After the main breakers have been opened, the switches to the rheostat shunting relays should be opened. The load can be shifted between machines by the manipulation of the voltage-limiting rheostat. In placing another unit on the bus, the switches to the rheostat shunting relays should be closed first and the machine voltage made equal to the bus voltage for paralleling by varying the voltage-limiting rheostat. Every movement can be made with ease and deliberation, as the operation is the same as on hand control. After the machine is on the bus, its share of the load can be placed on it by cutting out the necessary amount of the voltage-limiting rheostat.

Summing up the direct-current regulators, it is seen that they are extremely simple in principle and operation. They are inherently stable, thus no complicated system is necessary to prevent hunting; that is, surging of the voltage above and below normal. Only a minimum amount of attention is required and this in keeping the contacts and dashpot clean.

New Type of Multiduct Strainer

A new type of strainer for removing solid matter from water, oil or other liquids, and one in which the straining elements are revolved to a common chamber for removal and cleaning, has recently been developed by the Blackburn-Smith Corporation, New York City.

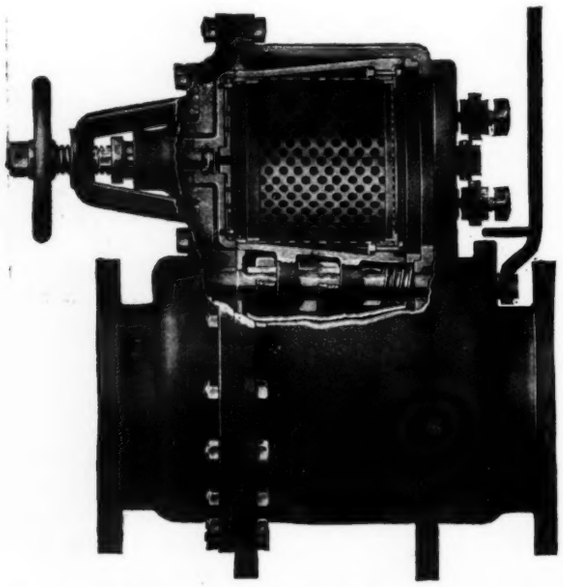


FIG. 1—GENERAL VIEW OF STRAINER SHOWING ONE STRAINER BASKET IN POSITION FOR CLEANING

The general features of the strainer are illustrated in Fig. 1, which shows a strainer basket in position for cleaning. The casing is in two parts, bolted together. The inlet and outlet nozzles are so located as to bring the piping connections in line.

The inner construction of the strainer proper is shown in Fig. 2. The cylindrical strainer baskets are

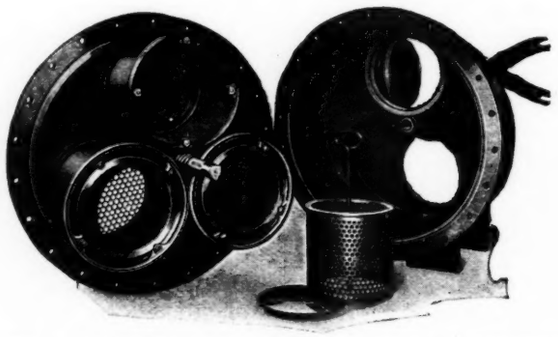


FIG. 2—EACH BASKET IS REVOLVED TO A COMMON CHAMBER FOR CLEANING

held in three bell-shaped conduits equally spaced in a circular plate. This plate is rotated in a groove provided at the joint between the two parts of the outer casing. Each of the three conduits is fastened to a central shaft, by means of which it is revolved to the cleaning chamber. With this arrangement two strainers are always in service while the third is in position for cleaning.

A valve arrangement, clearly shown in Fig. 1, is provided for shutting the liquid off the conduit containing the strainer basket to be cleaned. The opposite end of the cleaning chamber is provided with a hinged lid through which the basket is removed for cleaning.

To remove the basket, a handle is first screwed into the circular removing plate, which is held against the valve disk by spring latches. This plate is first pulled against the open end of the basket and prevents the contents from spilling as the basket is removed.

The strainer is built for a working pressure of 125 lb. The basket mesh is $\frac{3}{8}$ in., and the ratio of effective straining area to the area of the inlet is approximately three to one. The strainer is made in standard pipe sizes.

"Hardness" is frequently classified as "temporary" hardness and "permanent" hardness on the basis of the ease of its removal by heating the water. Suppose that the hardness of a certain water is measured by the amount of standard soap solution required to form a permanent lather. The result obtained is the "total" hardness, the sum of the temporary and the permanent hardness. If, now, a sample of this water is heated to the boiling point, some of the scale-forming compounds are immediately precipitated. The substances precipitated represent the temporary hardness, and what is left is the permanent hardness. The latter can be measured by another test with the standard soap solution. Then the amount of temporary hardness is evidently the difference between the permanent hardness just found and the total hardness as originally measured.

Pulverized coal, which is at present being widely applied as fuel for steam boilers, has for many years been used for melting ladles of steel scrap.

How Sulphur in Fuel Affects Flue-Gas Composition and Computations

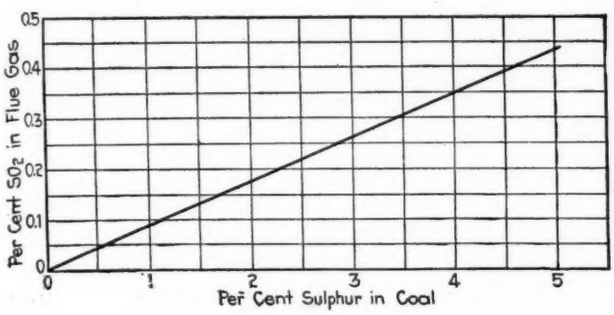
BY C. HAROLD BERRY, M.M.E.*

To best meet the needs of various types of readers, the material originally supplied by Mr. Berry has been broken up into two separate articles, this one and the one found on page 113 of this issue. The present article is a simple statement, for the busy engineer, of the general nature of the problem and of the conclusions reached by Mr. Berry. Enough is given to permit of direct application of the results. The other article is designed to meet the needs of those who wish to know all the steps in deriving the conclusions here given.

ALL fuels contain more or less sulphur, either free or in combination, which burns to sulphur dioxide or trioxide, two gases which unite with water to form sulphurous and sulphuric acid respectively. These acids give rise to serious corrosion where they come in contact with unprotected metal.

Further, in any flue-gas-analyzing apparatus both sulphur dioxide and sulphur trioxide will appear as carbon dioxide. That is, if we have 12 per cent CO_2 and 2 per cent SO_2, any flue-gas analyzer will give us a reading of 14 per cent CO_2, and only by comparatively elaborate chemical study can we detect even the presence of the SO_2, much less its amount.

Accordingly, it is not without value to raise two questions for study: (A) What is the relation between the sulphur content of the fuel and the percentage of sulphur-bearing gases in the flue gas? (B) What is



MAXIMUM PERCENTAGE OF SO_2

the effect of the sulphur-bearing gases on the computations usually based on the flue-gas analysis? The mathematical steps by which the answers to the questions were derived are given in the article beginning on page 113 of this issue. The answers themselves, with a few general words of explanation, will follow directly in the present article.

First, as to the question of the effect of sulphur in the coal on the percentage of SO_2 in the flue gas, the accompanying cut shows the relation for a coal containing 70 per cent carbon, 5 per cent hydrogen, 7 per cent oxygen, 1 per cent nitrogen, when burned completely with 10 per cent excess air. The smaller the amount of excess air, the greater, of course, is the effect of a given amount of sulphur in the coal. This curve, therefore, being based on a very small excess of air and running up to 5 per cent of sulphur (which is as high as is ordinarily found in bituminous coal) shows the maximum sulphur dioxide that may be expected. Moreover, since some of the sulphur will pass out unburned with the clinkers, and since some of the sulphur dioxide will dissolve in the water of the gas analyzer, the amount of sulphur dioxide actually appearing as carbon dioxide in the analysis would normally be considerably less than the amount indicated by the curve. There is, however, no way of telling how much less it would be, so the curve may be considered as indicating the upper limit. The important thing about this curve is that the sulphur dioxide is evidently very low in all practical cases. This fact should not lead us to belittle the serious effects of sulphurous gases on exposed metals. A very low concentration of gases so corrosive in their action, especially in the presence of water, can and does result in extensive damage to metals with which they come in contact.

Turning now to the effect of the sulphur dioxide on flue-gas computations, it should be remembered that, for the reason already stated, the sulphur burned will be less than the total sulphur in the coal, and the sulphur dioxide reported as carbon dioxide will be less than the total sulphur dioxide produced.

It is the general custom, after the total weight of dry flue gas per pound of carbon has been figured, to multiply this by the pounds of carbon burned per pound of fuel, in order to get the weight of flue gas per pound of fuel. Where the percentage reported as carbon dioxide really includes a small amount of sulphur dioxide, this method of computation is, of course, not strictly correct. It can be shown mathematically that if all the sulphur in the fuel remains unburned or is burned to sulphur dioxide, and if all the sulphur dioxide produced appears as carbon dioxide, and is so considered in figuring the weight of dry flue gas per pound of carbon by the ordinary method, the sulphur may be allowed for by replacing the ordinary factor [lb. of carbon burned per lb. fuel], by the following:

$$[(\text{lb. of carbon burned per lb. fuel}) + \tfrac{3}{8}\ (\text{lb. sulphur burned per lb. fuel})]$$

In other words, the weight of flue gas per pound of carbon is figured in the ordinary manner, assuming that no SO_2 is present, and this is then multiplied by the special factor to give the corrected weight per pound of fuel.

Inasmuch as the sulphur dioxide content of flue gas will always be small, often well within the limits of error of the gas analysis itself, and inasmuch as it is not at all certain that this sulphur dioxide all appears as carbon dioxide, and inasmuch as part of the sulphur generally remains unburned, it is questionable whether we are justified in making any corrections for sulphur, and it seems certain that we are not justified in splitting hairs when it comes to precise corrections.

*The Detroit Edison Company.

Accordingly, the factor developed in the foregoing may be taken as good enough for all ordinary testing work. If greater accuracy is necessary, efforts had best be made in the direction of determining the actual sulphur dioxide content of the gas rather than in finding corrections in the absence of this determination.

What is the magnitude of the correction given by this factor? With a coal of 70 per cent carbon and no sulphur, the factor is 0.70, while with a coal of 70 per cent carbon and 5 per cent sulphur, the factor is $0.70 + \frac{3}{8} \times 0.05 = 0.71875$—a difference of about 2.7 per cent. In other words, for fuels high in sulphur, the correction will approach 3 per cent, while for fuels containing only 1 or 2 per cent of sulphur, the correction will be less than 1 per cent and may as well be neglected.

If the flue gas contains hydrocarbons other than methane, that is, hydrocarbons having more than one atom of carbon per molecule, the correction would not reduce to any simple form, but the probability of such hydrocarbons appearing in appreciable quantities is so remote as to require no consideration.

The conclusion from the foregoing is that the effect of sulphur on the gas analysis and computation is small, and may be neglected except in refined tests with coal containing a high percentage of sulphur.

Improved Stoker Replacement Parts

Several novel features are employed in a new line of replacement parts for standard underfeed stokers, manufactured by the Combustion Appliances Co., of Youngstown, Ohio. The most important of these parts, which are designed for attaching to present installations, are a coaling ram and ram box. Fig. 1 shows this construction as applied to one of the well-known types of underfeed stokers. Both the coaling ram and lower ram are of rectangular cross-section instead of

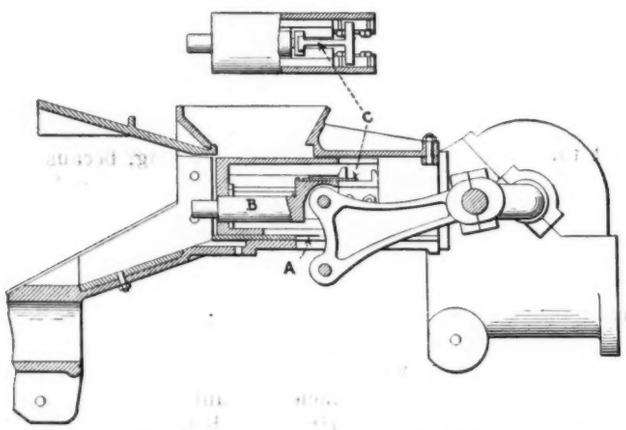


FIG. 1—RECTANGULAR COALING RAM FOR STANDARD UNDERFEED STOKERS

circular, this shape being used in order to obtain a large flat wearing surface which permits of a renewable wearing plate *A*. This plate can be shimmed up as wear takes place, thus keeping a minimum clearance to prevent sifting. Another advantage of the rectangular ram is that it forms a flat roof of coal in the hopper instead of the arched roof formed by the round rams. The flat roof will break down, so that there is no chance for the ram to work back and forth in a tunnel and not deliver coal to the retort.

The crosshead inside of the coaling ram is fitted with an extension *B* in the form of a small ram which projects through the face of the coaling ram. The coaling ram is pulled forward by the crosshead through a small steel link *C* in tension. The tensile strength of this safety link is such that it will break before a dangerous strain can be put on the stoker, due to tramp iron or other foreign material in the fuel fouling the coaling ram, or due to the fuel packing in the throat

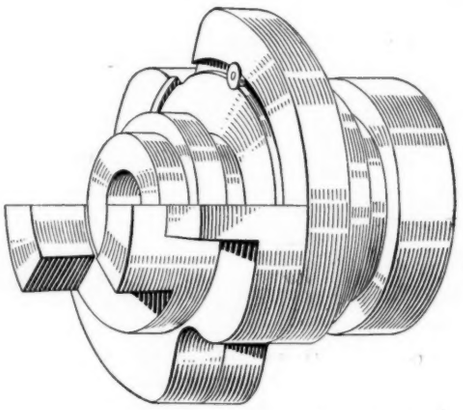


FIG. 2—SHIFTING CLUTCH FITTED WITH SHEARING PIN

of the retort. When the link breaks or is removed, the small ram passes through the face of the coaling ram and will dislodge the obstruction if it is not too long, or if the fuel packs in the throat of the retort and breaks the link, the poker, being of small diameter, will punch a hole in the packed coal, which relieves the condition so the fuel can be moved when a new link is inserted.

The ram box, which is of heavy construction, has liners and wearing plates at points subject to wear. It is cast smooth and to size, so that it is not necessary to machine off the hard surface of the castings.

In addition to the rectangular safety ram and ram boxes this line includes an improved stoker clutch, shown in Fig. 2, also a special type of coal plate extension and tuyere plates and a quick-detachable extension-grate driving mechanism for use on stokers having a reciprocating-type extension grate.

The jaws of the clutch, shown in Fig. 2, are held to the body by means of a tongue-and-groove construction which keeps the faces together throughout the whole diameter, and a groove is cut in the faces on the shearing-pin circle so that the pin, if it does not shear smoothly, cannot jam the clutch or cut the faces. Recesses are provided in both flanges of the clutch so that the two pieces of a sheared pin can be removed easily. A shifting lever is designed to be used in connection with this clutch, which is disengaged all the time except when actually shifting.

The coal-plate extensions and tuyere plates are made so that the parts that burn, which are but a small portion of the whole casting, can be renewed without having to renew the whole casting and without disturbing the tuyeres.

The extension grate is so constructed, that, by simply raising the back end of the grate and skidding it out on the dump plates, it can be removed for cleaning and repairing without the necessity of removing pins and cotters. The grate bars are not bolted to the frame, but are held in place by lugs that fit into sockets in the grate frame.

Reminiscences of a Veteran Mechanical Engineer—V

Power Engineering on the Erie Canal, and Some Tests Made in That Development

By W. D. ODELL

The next issue of the Reminiscences will be about some incidents connected with the indicator work, which led the author to meetings with Thomas A. Edison and Benjamin Parks.

DURING the late sixties and early seventies there was much agitation over the use of steam as a motive power on the state canals. Several attempts had been made to substitute steam in place of animal power with but little success. One of these attempts had been made by the late Henry R. Worthington, Sen., and though his steam canal boat was not a pronounced success, it led up to the invention of the direct-acting steam pump, which has been of such inestimable value to mankind.

To a proper understanding of the question of the use of steam on the canals, it may be advisable to state that the Legislature of the State of New York, April 28, 1871, passed "An Act to foster and develop the internal commerce of the State, by inviting and rewarding the practical and profitable introduction upon the canals of steam, caloric, electricity or any motor other than animal power, for the propulsion of boats; $100,000 was appropriated to be paid to the owners of successful plans not exceeding three in number." A commission, composed of George B. McClellan, Horatio Seymour, Erastus S. Prosser, David Dows, George Geddes, Van R. Richmond, Willis S. Nelson, George W. Chapman, William W. Wright and John D. Foy, was appointed to "practically test and examine inventions, or any and all devices which might be submitted to them for propelling boats upon the canal by any other motor than animal power."

In reading up the reports of the "practical tests" submitted to the legislature in 1872, 1873 and 1874, one is impressed with the enormous amount of guesswork that was allowed to pass muster at that time, and we will digress a bit to look at a few samples and so understand why Mr. Seymour[1] could not depend on them and wanted to get reliable data.

Take, for instance, the case of a boat fitted with a 12x12-in. cylinder; the report says "the average steam pressure was 68.9 lb.; revolutions of the screw 89.4 per minute; horsepower 38.6." Some idea of the process by which these queer conclusions were reached may be obtained by quoting from the reports.

> The data from which the former has been estimated, were determined by observations taken at intervals of fifteen minutes for the entire run of sixteen miles and are therefore reliable, but in regard to the coal I am not so certain. Having ascertained the weight of a bucket of coal, the engineer was required to report the number of buckets used, and the statement above is based on his report.

[1] N. Y. State Engineer.

Again, take the case of another boat fitted with compound cylinders of 7 and 12 in. diameter respectively, and with a stroke of piston of 12 in. The report goes on to state in reference to this "practical test,"

Steam, high-pressure cylinder, lb	74
Steam, low-pressure cylinder, lb.	18.75
Vacuum, in.	15
Revolutions per minute	115
Cutoff in each cylinder	¾

With these data an approximate estimate of the power is made thus:

Speed of pistons, ft. per min.	230
Area of high pressure piston, sq. in.	113.09
Mean pressure, per cent of initial	96
Mean pressure on high-pressure piston, per square inch, lb. (72 + 14.8) 0.96	83.23
Deduct back pressure (18.74 + 14.7)	33.45
Mean effective pressure on high-pressure piston, lb. per sq. in.,	49.78
Mean pressure on low-pressure piston, lb. per sq.in. (18.75 + 14.7) 0.96	32.11
Deduct back pressure, half atmosphere	7.35
Mean effective pressure on low-pressure piston, lb. per sq.in.,	24.76
Total mean effective pressure on high-pressure piston, lb. (38.48 × 49.78)	1,915.53
Total mean effective pressure on low-pressure piston, lb. (113.09 × 24.76)	2,800.11
Therefore $\frac{(1{,}915.53 + 2{,}800.11)}{33{,}000} \times 230$	32.87

After studying such data as the foregoing and being unable to get anywhere with it, Mr. Seymour became convinced it would be good engineering to deepen the canal one foot by taking the dirt from the bottom and placing it on the banks, and at the same time to lengthen the locks so that two boats could be locked through at the same time; but he wanted certain reliable data to lay before the legislature in case it became necessary to ask for an appropriation, and he appealed to his friend, the late James H. Blessing, of Albany (to whom the writer has also referred in a former article), to get these data for him. This Mr. Blessing, because of his other interests, could not do so, but referred Mr. Seymour to the writer, and it is the methods of making the tests and the wonderful results that grew out of them that I will try to chronicle.

In order the better to understand the difficulties the canal boatmen had to contend with, Mr. Seymour determined to make the entire trip from Buffalo to New York on the boats that were to be used for this test and personally note every obstacle encountered by a steam canal boat on a regular trip through the entire length of the canal, and then down the Hudson River to Pier 8, East River, New York.

The boats selected for the trip were the steamer "Emma" and consort "Hathaway," operated and owned by Captain Hathaway. They were of the ordinary model at that time used on the canals, the steamer pushing its consort, the "Hathaway," ahead of it, and a singular thing, as it at the time appeared to the writer, was that the consort acted as the rudder.

The steamer "Emma" was fitted with a simple upright engine, 12 in. diameter of cylinder, and 16-in. stroke, plain slide valves, with adjustable cutoff arranged to be worked from the pilot house.

The engine was condensing, and all water of condensation was returned to the boiler as fast as made, by a small plunger pump worked from the crosshead of the air pump. The propeller wheel was of peculiar design, in that a hub 4 ft. in diameter had four blades, each 2 ft. long, bolted to it. This made the diameter of the wheel 8 ft., with a pitch of 6 ft.

The upright tubular boiler, of ample capacity, fitted with internal magazine, would hold 700 lb. of coal. The magazine was charged from the deck, where the coal bunkers were also located. Artificial draft was produced by a blower, driven direct from the crankshaft, and the general design of the entire plant was admirable, the principal defects being in the proportion of its various parts.

The principal instruments used during the test were the steam-engine indicator attached to the cylinder by short direct connections. A pyrometer was placed in the base of the stack. A small platform scales was lent by the Buffalo Scales Co., and on this every pound of coal that went into the magazine and every pound of ashes taken from the ashpit was weighed at each change of watch. A revolution counter of new and unique design was lent by Frank J. Burns, of Buffalo. The steam and vacuum gages were tested by the indicator and variations noted. To the side of the forward boat a tachometer was secured by an angle-iron frame and its revolutions recorded on deck by electricity. By the use of this tachometer the speed of the boat through the current was obtained, and it was the sole duty of the State Engineer to get these records and note the time the boats passed certain prearranged points.

Everything being ready, the steamer was loaded with 7,300 bushels of wheat, and her consort was loaded with 7,800 bushels, so the united cargoes were 15,800 bushels of wheat, or about 430 tons.

The start from Buffalo was made at 1:35 p.m., July 11, 1879, but owing to detentions caused principally by low water in the canal, the boats did not reach Pier 8 East River, New York, until 8:40 p.m. July 21.

The following extracts from the data obtained will show the amount and cost in fuel of the distance traveled.

FROM BUFFALO TO ALBANY

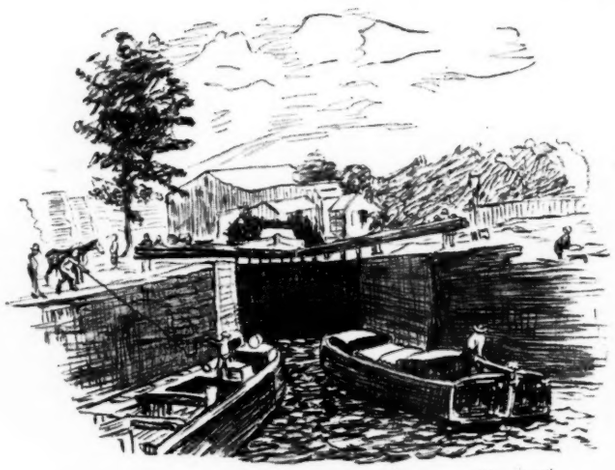
Distance, miles	352
Mean effective area of piston, in.	111.42
Time from Buffalo to Albany, hours	197.5
Average revolutions per minute	45.2
Mean effective pressure at 45.2 revolutions, lb.	22
Piston speed at 45.2 rev. per min., ft.	120.5
Total coal burned, lb.	12,950
Total ashes made, lb.	1,807
Per cent of ashes	13.95
Coal burned per hour, lb.	65.5
Average i. hp.	8.95
Coal burned per i. hp., lb.	7.31
Combustible per i. hp., lb.	6.3
Coal burned per mile, lb.	36.79
Average miles run per hour	1.78
Average boiler pressure, lb.	76

FROM ALBANY TO NEW YORK

Distance, miles	143
Time, hours	48.6
Average revolutions per minute	59.2
Mean effective pressure 59.2 rev., lb.	29
Piston speed at 59.2 rev., ft.	157.8
Total coal burned, lb.	4,655
Total ashes made, lb.	655
Per cent of ashes	1,407
Coal burned per hour, lb.	95.7
Average indicated hp.	15.4
Coal burned per i. hp., lb.	6.2
Combustible per i. hp., lb.	5.34
Coal burned per mile, lb.	32.55
Average miles per hour	2.49
Average boiler pressure, lb.	65

The cutoff was inoperative at less than three-quarters stroke, a defect that was not discovered until too late to remedy it before starting on the trip. This, with other defects, caused a useless consumption of coal estimated at 3,521 lb. during the trip, but notwithstanding this, it was demonstrated that with an additional depth of one foot of water in the canal and some slight improvements at the locks, grain could be carried from Buffalo to New York at a price that would pay the owners of steam canal boats, even at the then prevailing low rates of freight. In fact, the rates were so low at the time this test was made that the horse-boatmen could not make their expenses and laid up their boats whenever they could get other work for their teams, and yet I was told by Captain Hathaway later on, that after paying all expenses and 6 per cent on the money invested in boats, and 10 per cent as a sinking fund, the season's work had netted him $2,600 as compensation for his wife's and his own services.

When we had about reached our journey's end, I asked Mr. Seymour if he wished me to work up the data obtained or if he would take it. He replied, "Oh, we have a lot of clerks lying around the capitol, and I think it best to let them work it up," but later on



ENTRANCE TO ERIE CANAL AT TROY, N. Y.
After a drawing by Edwin A. Abbey in 1874.

he sent for me and said he wanted to know the power used per mile over three different depths of water in the canal. I think it was 6 ft., 7 ft. and 8 ft., although I am not certain after all these years, but I replied, "I do not know any more about the depth of water in the canal than I do about the man in the moon, but your men know just where the boats were all through the trip, and on my indicator cards the time taken was noted, and if you will pick out three cards, when passing over these different depths of water I can tell you." This was done and as Mr. Seymour told me later on, it was most convincing to the legislature when he asked for an appropriation of $9,000,000 to deepen certain portions of the canal one foot and lengthen the locks so that two boats could be locked through at one time. Before that first appropriation was used up, the improvement was so marked that another $5,000,000 was made to continue the good work; then, as the full benefit became known, the question came up, Why not make a barge canal of it? and the question was submitted to the citizens of the state, who voted to appropriate $100,000,000 to accomplish this purpose.

There are many things of absorbing interest about this great work, but they cannot be given here; there is enough here to show how "great oaks from little acorns grow."

Radiant Heat from New Type of Furnace

While most modern boiler furnaces transmit some part of the heat to the water-heating surfaces by radiation, they still depend to a large extent upon convection. Special interest therefore attaches to a new type of furnace in which by far the largest part of the total heat transfer (depending on the particular design of boiler and furnace) is accomplished by pure radiation from the *outside* of the combustion chamber.

In this furnace combustion of the gaseous, liquid or powdered fuel takes place in a long two-pass flue chamber constructed entirely of carborundum refractory tiles. The major portions of the surfaces to be heated envelop this chamber to absorb the heat which is transmitted directly through the incandescent tiles and radiated from their outer surfaces. By the time the gases reach the outlet of the long inclosed combustion chamber, the gas temperature is down to about 1,200 deg. F. A considerable part of the remaining heat may then be recovered by passing the flue gases through a bank of ordinary boiler or economizer tubes. In the latter case little or no convection heating surface whatever is needed in the boiler proper.

This furnace, known as the Cannon Radiating Furnace and manufactured by The Carborundum Company, Refractory Division, Perth Amboy, N. J., is made in various forms, of which the experimental installation shown in the accompanying illustration is typical. This shows an oil-burning furnace erected for test at the Massachusetts Institute of Technology. In studying this drawing, the essential features of the furnace should be distinguished from those that were merely incidental to the test. All the outer brickwork can be classed as incidental because it would be entirely eliminated in a commercial installation.

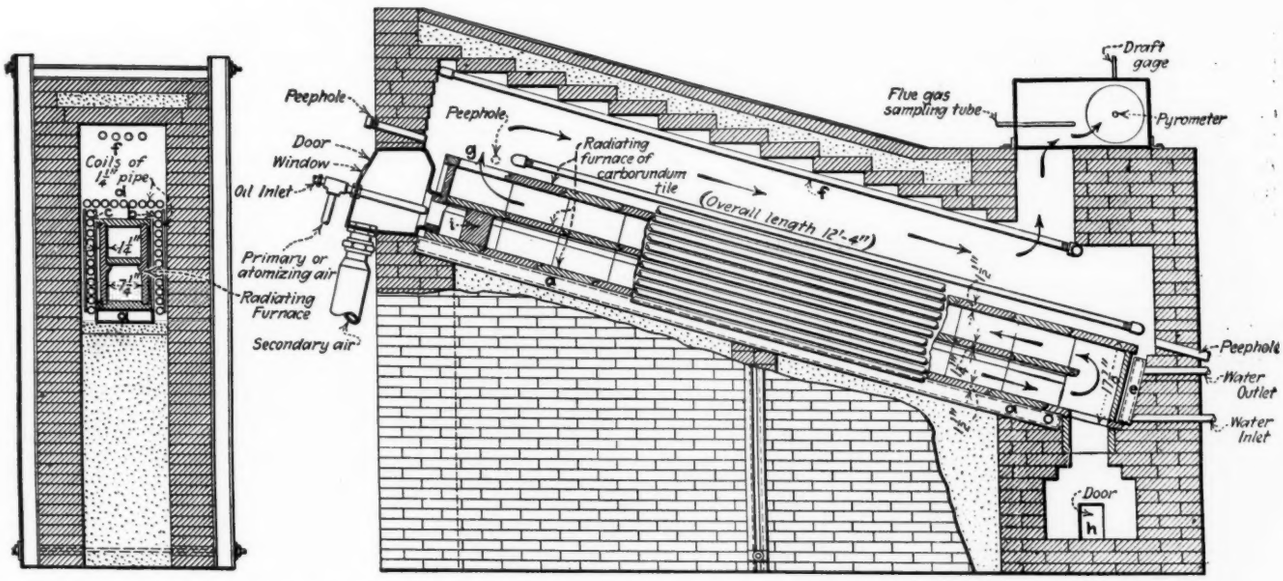
The furnace proper appears as a long double flue constructed of specially molded carborundum tiles. These are laid together with overlapping and interlocking joints, no bonding cement being used. A horizontal partition practically doubles the length of the combustion chamber. The oil burner is mounted at the left end of the lower passage, as shown, secondary air entering through the annular space around the burner. The wedge-shaped carborundum block *i* serves to facilitate ignition and mixing.

The burning gases travel the whole length of the lower chamber and then return to the flue by means of the upper chamber, thereby traversing (in the experimental installation) a total path of 23.88 ft. through a chamber whose average cross-section is 0.337 sq.ft. The long, narrow combustion space insures continual mixing and remixing of the air and oil vapor in close proximity to incandescent walls. By cutting down the air supply until the flame extends nearly to the outlet flue it is said to be possible to obtain complete combustion with as little as 3 per cent excess air.

The long combustion space of small cross-sectional area also gives a high ratio of radiating surface to combustion volume, and thus accelerates the transmission of the heat generated through the walls. To absorb this heat, the furnace is surrounded by water-heating surface on all sides. In the test plant ordinary 1¼-in. piping with return bends was used on the top and sides, while the radiation from the bottom and lower end was absorbed in flat water containers of rectangular section. As a matter of convenience another row of tubes, heated mainly by convection, was installed above the furnace to further cool the gases leaving the furnace flue. The construction used in the test plant did not permit of steam generation in any of the coils.

No attempt was made in the test installation to obtain high over-all efficiency, the object being to determine the quality and maximum rate of combustion and the rate of heat transfer through the furnace walls. Furnace-wall and flame temperatures were not taken because of the difficulties involved.

The average rate of combustion during the test was 275,000 B.t.u. per cubic foot per hour. When the test period was completed, the fuel feed was increased (unofficially) from 109 lb. per hour to 140 lb. with a



CROSS-SECTIONAL VIEWS OF EXPERIMENTAL FURNACE AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

corresponding increase in the combustion rate to 350,000 B.t.u. per cubic foot per hour. This limit was fixed by the capacity of the oil burners. After operating at this rate for an hour, the supply of fuel and air was stopped instantly so that observers could note the interior of the furnace. The estimated temperature at the instant of shutdown was only 1,600 deg. F. The furnace walls showed no signs of having been used.

It will be noted from the test report that the heat absorbed per square foot of heating surface per hour in coils *b*, *c* and *d* would have approximated the values shown for coils *a* and *e* if only the half of the tube surface exposed to radiant heat had been considered.

As previously stated, all the outer brickwork would be dispensed with in a commercial installation, the furnace being then supported on a steel frame. An envelope of low-temperature heat insulation would be applied outside of the tubes to prevent loss of heat by radiation.

Carborundum refractories have made this type of furnace possible. There are two reasons for this, the first being the remarkable resistance of carborundum to high temperatures. The other is its high coefficient of heat transfer, which is said to be about eight times that of ordinary firebrick at the existing temperatures. As a result high rates of combustion may be maintained, together with a minimum of excess air, without danger to the refractories.

The opening and pit shown at the right end of the lower chamber is unnecessary with liquid or gaseous fuel, its purpose being to collect any accumulation of ash that might occur if powdered fuel were used. Preliminary tests recently made with powdered coal gave excellent results at combustion rates as high as 250,000 B.t.u. per cu.ft., the flue gas then showing 14 per cent CO_2, no CO and 4.5 per cent O_2.

The following report is slightly condensed from the original test report of Prof. J. J. Eames, of the Massachusetts Institute of Technology:

Report of Test on a Cannon Experimental Furnace

This test was run on a small furnace built in the Mechanical Engineering Laboratory of the Massachusetts Institute of Technology, to determine what maximum rate of complete combustion could be maintained per cubic foot of combustion space.

Method of Conducting Test

The burner was operated throughout the test period by H. B. Cannon. It was adjusted so as to have combustion continue to the exit from the carborundum chamber and also to have it complete at this point.

All observations and measurements for the test were made by members of the Engineering Laboratory Instructing Staff except for the flue-gas analysis, where two graduate students assisted.

The oil used was determined by differences in weight. The water circulated was weighed continuously for each coil separately, and the temperatures determined at entrance and exit.

The flue-gas temperature was taken at the uptake by means of a thermo-couple pyrometer. Two Orsats were used for making gas analysis, and an average of six samples of gas per hour were analyzed. A CO_2 recording gage was also used.

The weighing scales used were tested before using and the thermometers checked up at the temperatures indicated by each and proper corrections made. It is believed that any error in the recorded data does not exceed one per cent.

Data and Results

Test made in Mechanical Engineering Laboratory of Mass. Inst. of Tech.	
Date of test	April 4 and 5, 1923
Duration	22 hours
Fuel:	
Light gravity oil	Gravity 36.5 deg. Baume at 83 deg. F.
Heat of combustion	20,060 B.t.u
Burner	Air atomization
Furnace:	
Constructed of carborundum tile, arranged for two passes of the gases.	
Cross-section area of lower or first pass	48.9 sq.in.
Cross-section area of upper or second pass	48.1 sq.in.
Inside length of furnace	11.94 ft.
Total length of combustion chamber	23.88 ft.
Volume of combustion space	8.0 cu.ft.
Exterior radiating surface of furnace	62.8 sq.ft.
Square feet of heating surface:	
Box section (*a*) under furnace (top and two sides)	17.2 sq.ft.
Coil (*b*) on right side	58.2 sq.ft.
Coil (*c*) on left side	58.2 sq.ft.
Coil (*d*) of top	44.6 sq.ft.
Box section (*e*) at rear (front and 4 edges)	1.8 sq.ft.
Coil (*f*) in gas passage between furnace outlet and uptake	19.9 sq.ft.
Total heating surface	199.9 sq.ft.
Average Pressures and Temperatures:	
Room temperature (deg. F.)	70.1
Oil pressure at burner (lb. per sq.in.)	20.6
Oil temperature at burner (deg. F.)	204.4
Atomizing air pressure (inches mercury)	3.33
Draft at uptake (inches of water)	0.064
Temperature of flue gases at uptake (deg. F.)	710
Temperature of feed water (deg. F.)	39.4

Total Weights of Water Heated and B.t.u. Absorbed:	Lb.	B.t.u.
In box section (*a*) under furnace	37,260	4,512,100
In coil (*b*) on right side of furnace	65,730	8,242,500
In coil (*c*) on left side of furnace	66,700	8,451,000
In coil (*d*) on top of furnace	46,150	5,731,700
In box section at rear of furnace	15,100	498,300
Total water heated by radiation	230,940	27,435,600
Heated in coil in gas passage	258,100	5,549,300
Grand total of water heated	489,040	32,984,900

Heat Absorbed per Sq.Ft. of Heating Surface per Hour:	
In box section (*a*) under furnace	11,900 B.t.u.
In coil (*b*) on right side of furnace	6,440 B.t.u.
In coil (*c*) on left side of furnace	6,600 B.t.u.
In coil (*d*) on top of furnace	5,850 B.t.u.
In box section (*e*) at rear of furnace	12,590 B.t.u.
In coil (*f*) in final gas passage	12,680 B.t.u.
Oil Burned:	
Total oil burned	2,406 lb.
Oil burned per hour average	109.4 lb.
Oil burned per cu.ft. of comb. space per hour	13.68 lb.
B.t.u. developed per cu.ft. of comb. space per hour	274,300 B.t.u.
Fuel analysis	Carbon, 86.0 per cent; hydrogen, 13.1 per cent
Combustion:	
Flue-gas analysis	CO_2, 13.55; O_2, 2.21; CO,, .09; N_2, 84.15
Excess air supplied	10.9 per cent

Heat Balance:	B.t.u.	Per Cent
Heat absorbed per pound of fuel burned.	1,875	9.35
In box section under furnace	3,426	17.08
In coil on right side of furnace	3,513	17.51
In coil on left side of furnace	2,382	11.88
In coil on top of furnace	207	1.03
In box section at rear of furnace	11,403	56.85
Total heat by radiation	2,306	11.50
In coil in gas passage	13,709	68.35
Total heat absorbed by water	1,585	7.90
Heat lost in moisture of formation	2,440	12.13
Heat lost in dry flue gas	58	.29
Heat lost by incomplete combustion of carbon	2,276	11.33
Heat lost by radiation and unaccounted for	20,068	100.00
Heat of combustion of 1 lb. of oil		

Discussion

No charge has been made against the furnace for steam used for preheating the oil or for that used in driving the oil pump and the air blower.

The principal result sought was the rate of complete combustion attainable. This was found to average 13.68 lb. of oil per cubic foot of combustion space per hour. The rate of heat absorption by the water is 187,000 B.t.u. per cubic foot of combustion space per hour. This last figure could be materially increased if proper and sufficient heating surface were provided.

It should be noted in addition that the excess air supply was only 10.9 per cent and that the combustion was practically complete, there being less than 0.1 per cent of CO in the exit gases.

In considering the reported heat transferred by radiation per square foot of heating surface per hour, attention is called to the fact that the entire external pipe surface in coils *b*, *c* and *d* has been used. Also the edges of the rectangular water legs *a* and *e* have been included. This entire surface is not exposed to direct radiation from the carborundum furnace, and the values reported are therefore much lower than they would be if the whole surface could be so exposed. The furnace lining appears unaffected by its use thus far.

U. S. Coal Commission Reports on Anthracite

Urges Regulation of Coal Industry As a Public Utility with Provision for Government Operation Whenever Miners and Operators Fail to Agree

THE fundamental fact in the anthracite coal problem is that heretofore these limited and exhaustible natural deposits have been in the absolute private possession of their legal owners, to be developed or withheld at will, to be leased for such royalties as could be exacted, to be transported and distributed at such rates and in such manner as a double-headed railroad and coal combination might find most advantageous from the point of view of private profit, to be sold at such prices as could be maintained by the restriction of output and the elimination of independent competitors, through such means as the maintenance of freight rates burdensome except to those who, owning both mines and railroads, could afford to be indifferent as to whether their revenue came from the one source or the other.

The Commission does not recommend the abolition of existing property rights, however much might be said for the view that mineral deposits should have been held from the beginning as national rather than individual property. The Commission does not recommend government ownership either by purchase at present value or by expropriation. It does, however, hold the view that a limited natural monopoly like anthracite, held by a relatively small number of individuals, estates and companies, and supplying a necessity of life for millions of our people, cannot continue to be treated as if it were not affected by a public interest.

Coal is quite as much a public necessity as gas, street-railway service, or any other service or commodity that has been brought under public regulation. There should be no secrets from the public in regard to mining costs, profits, salaries, wages or corporate relations.

The time has certainly come to establish the same controlling idea in the anthracite-coal industry. There is not as yet a sufficient basis in knowledge or experience to determine what form of control or regulation will ultimately be most advantageous. What is clear is that in the operation of coal mines, as in the operation of railroads, telephones, water companies or banks, the public interest must be respected and served, and that this requirement places limitation on the rights of owners of coal lands, operators, mine workers, carriers and dealers. The Commission believes that the principle of individual and corporate responsibility should be maintained as most likely to insure economical and efficient management of the industry, and that the public interest may be adequately safeguarded by the creation of a governmental authority with power to require financial and operating reports, to prescribe uniform methods of cost accounting, and determine conditions on which coal may be shipped in interstate commerce.

The President of the United States should be authorized by act of Congress to declare that a national emergency exists whenever through failure of operators and miners in the anthracite industry to agree upon the terms of employment or for any other reason there is a suspension of mining operations seriously interrupting the normal supply of anthracite fuel in interstate commerce; and to take over the operation of the mines and the transportation and distribution and marketing of the product, with full power to determine the wages to be paid to mine workers, the prices at which the coal shall be sold and, subject to court review, the compensation to be paid to land- and mine-owners.

On these subjects more definite recommendations will be reserved for the final report of the Commission since they apply to both branches of the industry.

Price Advance in Ten Years

The average retail price of stove anthracite in 1913 in Boston and Washington was $8.25 and $7.50, respectively, the former, however, being the price of a short or net ton, the latter that of a long or gross ton. In 1923 the corresponding retail prices are $15 for Boston and $15.39 for Washington. Since 1913 the freight rates from the anthracite mines to these two cities have increased $1.25 and $1.14. Eight of the larger coal companies, most of them still closely affiliated with the railroads, are grouped together in price quotations and their product is known as "company" coal, in contrast with the "independent" coal produced by 100 or more smaller "individual" companies. In 1913 the average mine price of stove anthracite was $3.53 a gross ton; today the quotations are $8 to $8.35 a gross ton for "company" and $8.50 to $11.50 for "independent" coal.

An analysis of the consumer's dollar based on an examination of the books of retail dealers in several of the larger cities may serve to show the component parts of the price he paid. For example, in November, 1922, in Boston the average retail price of stove coal at the customer's curb was $15.68 a net ton. At this rate a dollar paid for 128 lb. of coal. Of this dollar 45c. represented the sales price at the mine, 23c. the charge for freight, and 32c. the share of the dealer. In New York the average price was $13.77. Here the dollar paid for 145 lb. of coal, and 56c., 18c. and 26c. represented the division between mine, railroads and dealers.

It is interesting to the public to know what part of the consumer's dollar commonly goes for profit of operator or retail distributor. A buyer of domestic anthracite in Boston in November, 1922, paid something like 11c. out of every dollar in the form of profit to the producer or retailer of coal. Of this about 4c. went to his local retailer and nearly 7c. to the producer, for his profit on mining and sale at wholesale. Practically the same figures hold for Washington, where the same month the householder paid 3c. out of every dollar in profit to the retail coal merchant and nearly 9c. out of every dollar as profit to the producer and wholesale distributor of coal.

The speculative activity of the independent wholesaler in time of shortage adds to the wide spread in the prevailing prices of anthracite, and this activity may result not only in largely increased profits for individual jobbers but in pyramiding profits by multiple sales among jobbers. The Commission's study of carloads of high-priced coal selected at random from shipments to New

England during the last fall and winter disclosed considerable buying and selling among jobbers with consequent pyramiding of their margins, varying on different sales from 15c. to $4.25, the amount which a Boston jobber in December, 1922, added to the $9 mine price of a car of stove anthracite. A considerable number of sales were reported at margins from 75c. to $1.50 a gross ton. It must not be forgotten that the jobber of this type physically handles no coal whatever; his is only a credit and bookkeeping business.

As so large a part of the anthracite consumer's dollar goes as freight charges, a material reduction in the price of coal might come through a reduction of freight rates. With a keen appreciation of the public demand for the scrutiny of every item in the cost of anthracite, the Coal Commission urges upon the Interstate Commerce Commission, the duly constituted agency of the federal government, a re-examination of the reasonableness of anthracite freight rates. The pending separation of carriers and mining companies in the three larger systems makes opportune the reconsideration of the subject by the Interstate Commerce Commission.

Influence of Increased Labor Cost

It is found that all the factors involved in mining costs contribute to the increase in mine prices. In the 10 years under review by the Commission's accounting staff, labor costs in the production of fresh-mined coal have risen from $1.56 a gross ton in 1913 to $4.12 in the first quarter of 1923, the cost of supplies from 35 to 71 cents, and general expenses from 32 to 92 cents. Labor cost bears about the same relation to total mine cost in 1923 (71.7 per cent) as in 1913 (70 per cent); supplies cost relatively less in 1923; and general expenses are relatively higher in 1923.

The total range in the average mine cost of a ton of coal with the nine railroad companies has been from $2.23 in 1913 to $5.75 in 1923. With three independent companies for which there are continuous cost records, the corresponding change has been from an average cost of $2.50 in 1913 to $6.32 in 1923. Examined in detail, the increase in mine costs for these twelve companies was moderate until 1918, when for three successive years there was an annual jump of approximately a dollar. To these increases, change in wage rates, rising

AVERAGE DAYS WORKED BY ANTHRACITE MINES (1890—1921
(Based on statistics of the U. S. Geological Survey)

Year	Days Worked	Year	Days Worked	Year	Days Worked	Year	Days Worked
1890	200	1900	166	1910	229	1920	271
1891	203	1901	196	1911	246	1921	271
1892	198	1902	(a) 116	1912	231		
1893	197	1903	206	1913	257		
1894	190	1904	200	1914	245		
1895	196	1905	215	1915	230		
1896	174	1906	195	1916	253		
1897	150	1907	220	1917	285		
1898	152	1908	200	1918	293		
1899	173	1909	(b)	1919	266		
Average	183	Average	190	Average	254		

(a) Strike (b) Not available.

prices for supplies, and increasing charges for royalty and depletion have all contributed, and the discussion of the first and largest item, labor costs, leads to the most extensive inquiry which this Commission has undertaken, covering the living conditions of the miners' families and the earnings and other labor conditions of the mine workers.

The 1920 census shows 147,456 anthracite mine workers. The average income from all sources was approximately $176 per month; 41 per cent had as much as this or more; 59 per cent had less. Nine families, or 1.2 per cent of the total families visited, had an average monthly income during the six months of less than $75; forty-seven families, or 6.6 per cent, had from $75 to $100; ninety-nine families, or 14 per cent, had from $100 to $125; one hundred and twenty-seven, or 17.8 per cent, had from $125 to $150; one hundred and thirty-seven, or 19.2 per cent, had from $150 to $175; one hundred, or 14.1 per cent, had from $175 to $200; and one hundred and ninety-three, or 27.1 per cent, had $200 or over.

About a third of the output of anthracite is mined under leases in which the operator pays the landowner a royalty. The royalties collected on fresh-mined coal

RELATIVE RATES OF PAY FOR COMPANY MINERS IN THE ANTHRACITE FIELD, 1903, 1912, 1923

No. of Operation	Hourly Rates April 1 1903	Hourly Rates April 1 1923	Relative Rates April 1 1903	Relative Rates May 20, 1912	Relative Rates April 1 1923
1	.235	.643	100	110	274
2	.235	.643	100	110	274
10	.245	.658	100	110	269
11	.230	.636	100	110	277
23	.266	.689	100	110	259
28	.222	.664	100	113	299
42	.252	.668	100	110	265
58	.258	.678	100	110	263
64	.244	.656	100	110	269

range from as low as 12c. on old flat-rate leases to as high as $1.50 per ton; on percentage leases and on certain stripping operations the rate is even higher. The royalty rate of the Girard estate leases for 1921 averaged $1.27 per ton on all coal mined, amounting to 2,983,723 tons.

The land-holding companies and estates thus share in the monopoly power possessed by the anthracite operations. To protect the public against abuse of this monopoly power, they should be required to file periodic statements of their costs and profits in relation to investment under the program of publicity elsewhere proposed.

The margin per ton between cost of production and net sales realization includes all the earnings from the mining of coal available for payments on account of capital, whether paid out in federal taxes, as interest, as dividends, or reserved as surplus. The margin will not show return on investment until the amount of the investment is established, but it will indicate whether over a period of years profits are increasing.

Measured by this margin per ton the anthracite operators are receiving much larger profits at present than they customarily did before the war. For the year 1913 nine "railroad" coal companies had an average margin of 36c. a ton. In the first quarter of 1923 the same operators received a margin over reported costs of 93c. a ton. But because of differences in accounting methods in respect to depletion and depreciation, these reported costs, although following the Treasury Department's requirements, are not strictly comparable with the costs as determined by the Federal Trade Commission for earlier years. To make them comparable it is necessary to deduct 14c. from the costs as now reported and add 14c. to the margin. This would make the 1923 margin $1.07 per ton, or three times the prewar margin.

Further evidence that the profits of the anthracite companies are increasing is found in the increase of their surplus accounts. There are five "railroad" coal companies engaged exclusively in the mining of coal that have been paying dividends in recent years. The total surplus of these five companies rose from $7,000,000 in 1911 to $52,000,000 in 1920. In other words it increased sevenfold in ten years. The following year (1921) it dropped to $36,000,000, chiefly because of the payment out of surplus during 1920 and 1921 of very large dividends by four of the five companies.

EDITORIALS

F. R. LOW, EDITOR

Hydro-Electric Plant Operation Offers Real Problem

WITH few exceptions the operation of hydro-electric plants has not been given the amount of attention that has been devoted to steam-electric stations. There is, however, just as sound economical reasons for careful analysis of operation in one case as in the other, and it is beginning to be realized that the operation of a hydro-electric plant is something more than starting and stopping the turbines. The idea that in general prevails in the public mind, that water for power generation does not cost anything, has undoubtedly had an influence upon the minds of many water-power plant operators.

It is a very real thing in a steam plant that when a ton of coal is burned it must be replaced by another at so much per ton. With water flowing continuously to a plant without any apparent effort on the part of anyone, it is not quite so easy to appreciate that every cubic foot has a tangible value just as every pound of coal or fuel oil has in a steam plant; nevertheless, they both cost so much per unit volume. Fuel is paid for at so much per ton or barrel at the time of purchase or shortly thereafter. The cost of water is represented in the carrying charges on the investment necessary to provide the works to bring it to the plant, and the operating costs.

The utilization of water to obtain the greatest number of kilowatt-hours from it, offers as many operating problems as getting the greatest number of kilowatt hours from fuel burned under boilers in steam plants. In fact, the operating problems of hydro-electric plants are probably more involved, since no two stream flows are alike, and there are also wide variations in temperature that may materially affect hydro-plant operation, which are not such important factors in a steam plant. Unfortunately, hydro-electric plants are not so well equipped to obtain an intelligent record of operation as steam plants are, nor up to the present time is it so easy to equip them.

In the steam plant a record of coal fired and the feed water supplied to the boilers gives a check from day to day on boiler operation, and the equipment for obtaining this record is comparatively simple. From the kilowatt-hours delivered to the busbars and the coal fired, the over-all thermal efficiency of the plant is obtained and can be checked each day. In water-power plants, if the water flow to the turbines is obtained in most cases, it must be checked back from the load on the unit and its efficiency. In a few installations only have provisions been made in hydro-plants for obtaining a continuous record of water flow, although a number of plants use power-discharge curves to show the most economical loading of the units and to use as a check on their operation, but this leaves a great deal to be desired in the way of a more simple method of obtaining a record of the flow of water to the turbine.

Be the conditions as they may, the fact remains that where the amount of water is limited, a material increase in the number of kilowatt-hours produced may be realized by careful analysis of operation. The proper distribution of load among the units; the number of units to keep in service to have them operating at the highest efficiency consistent with the load; maintaining the load on the station at a value to obtain the highest head without wasting water; predicting the quantity of water available—these and many other problems offer opportunities requiring operating skill equal to that required in any steam plant.

The Coal Industry a Utility

THE Federal Coal Commission, in its report just issued, has thrown a spotlight on the anthracite industry, penetrating the smoke screens of propaganda and laying bare some of the factors entering into the steadily mounting coal prices. Outstanding among these are:

Miners' wages have considerably more than doubled during the last ten years.

Royalties have become exorbitant, in some cases $1.50 a ton.

Freight rates are too high, from sixteen to thirty per cent of the retail price, and are reflected in the accumulated surpluses of several of the railroads that are under joint ownership with the coal mines; in the case of five "railroad" coal companies the total surplus increased seven-fold in ten years.

The general expense and profits of the operators are relatively higher than the increase in cost of production, being nearly three hundred per cent of what they were in 1913.

Excessive margins have been exacted by many wholesalers and retailers, and lack of uniformity in margins has stimulated speculative activity among independent wholesalers with consequent pyramiding of prices by multiple sales among jobbers.

That the Commission regards the anthracite industry as a limited natural monopoly, owing a service to the public rather than maximum profits to itself, and urges that it be regulated as a public utility, is especially gratifying in that it is in line with what *Power* has long been urging. Specific recommendations as to the form of regulation are reserved for the final report, but it is indicated that full publicity will be required as a check on hidden inflation.

Teeth are put into the report by recommending that the President be empowered to take over and operate the mines, transportation and distribution of the coal and to fix both wages and prices whenever failure of operators and miners to agree shall threaten the supply. This may not set well with either the operators or the miners, but in an emergency public interest is paramount to private. It will meet with general approval.

The personnel of the Federal Coal Commission precludes any charge of radicalism. Its recommendations are sound, and it would be well for both operators

and miners to accept them in the proper spirit. Failure to do so would undoubtedly result in Congress, in response to an enraged public opinion, passing more stringent and perhaps unsound legislation.

What effect the report will have on coal prices is uncertain. It probably will not result in any immediate reduction; although in time, if Congress follows out the recommendations, there may be some relief. It is certain, however, to exercise a material influence on the present and future negotiations between operators and miners and should tend to prevent further inflation as a result of threatened stoppage of supply. In any event it shows the consumer where his money goes.

Seventy-Five Per Cent Thermal Efficiency From the Oil Engine

THE thermal efficiency of the internal-combustion engine is so satisfactory, compared with that of a steam engine, that the possibilities of obtaining a 250 per cent increase in efficiency has been largely ignored. If, to obtain an efficiency of the order of thirty per cent, an initial investment of one hundred dollars per horsepower is proper, then it is well worth while to expend fifty dollars per horsepower if the results may be more than doubled.

The Still steam-oil engine was designed with the idea of recovering the heat absorbed by the cooling water of the oil engine as well as part of the exhaust heat. Doubtless this design is correct for certain specific conditions, but it would seem that the construction costs would be extremely high. In addition the total over-all efficiency reaches only forty per cent or so.

There is no reason why the efficiency of an ordinary oil engine should not by inexpensive auxiliaries be raised from thirty to seventy-five per cent. Taking a well-designed Diesel as an example, there is converted into power at the shaft approximately thirty per cent of the heat of the fuel; the cooling water absorbs about thirty-four per cent, while twenty-four per cent is lost through the exhaust.

The heat in the cooling water is at a comparatively high temperature level, around 140 degrees Fahrenheit. The exhaust gas temperature at the cylinder exit may be from six to seven hundred degrees in temperature. Operation of existing plants proves that of the exhaust gas heat fifty per cent may be recovered by suitable waste heat boilers. By passing the jacket water through the waste-heat boiler, it is possible to recover forty-six per cent of the heat generated in the cylinder, which is usually lost plus the heat converted into work, or a total of seventy-six per cent.

The objection usually raised is that this heat recovery, by reason of the small amount of fuel used, is negligible. In case of a thousand-horsepower plant the fuel consumption will total around four hundred pounds, or over seven million B.t.u. per hour. The amount usually thrown away will be over half of this, and by exhaust heaters or boilers over three million B.t.u. may be recovered. Since the usual small steam plant will not have boiler efficiency of over sixty per cent, the waste heat recovery is equivalent to a boiler fuel consumption of almost six million B.t.u., or 312 pounds of oil an hour. Transferred into dollars this means, with a fuel cost of four cents a gallon, a yearly saving of over fourteen thousand dollars.

In textile plants having need of hot water for process work this arrangement offers many possibilities. If steam is required, there is no reason why the waste-heat boiler should not either be used as an economizer or supplied with a separate oil-fired furnace to assist in the steam generation. Even in hotel and office-building plants the system should be economical.

Planning a Boiler Test

A PROPERLY conducted boiler test is expensive. Yet, large as this investment is, it often pays royally if those in charge have the purpose of the test clearly in mind and have carefully planned the procedure. Other things being equal, the cost of a boiler test increases almost in direct proportion to its length. It is possible to waste a considerable sum of money by making it longer than necessary. If, on the other hand, it is made too short, the results obtained may be so inaccurate as to be worthless.

In view of these facts there is no excuse for starting a boiler test without first clearly defining the objects to be attained and making a careful study to determine the best method of attaining them. The first matter to decide is the allowable percentage of error in the computed efficiency. There are still engineers who report boiler efficiencies to two decimal places, but those who have studied the matter look upon a boiler efficiency that can be *trusted* within two per cent as a fine piece of experimental work. More often than not the engineer must be content with a larger margin of error. After the permissible error has been agreed upon, the next question is how to keep within this margin at the least possible cost. There is no sense in spending large sums to cut the error a tenth of one per cent at one point while neglecting a no more costly opportunity to cut one per cent at another.

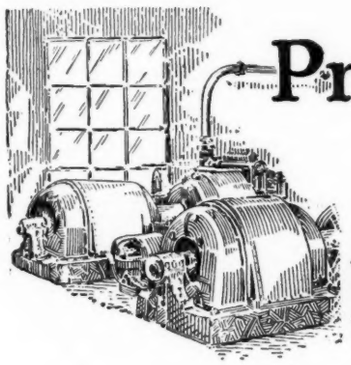
To keep the sum of all the errors within the given limits at the minimum of cost requires careful study, good judgment and some elementary knowledge of the theory of errors as applied to steam boilers. The latter is covered in a simple but practical manner by the article, "The Determination of Boiler Efficiency," on page 88. Engineers who may have occasion to make boiler tests should read this article carefully. Particular attention should be paid to the scientific method of determining the necessary length of the test to keep the error due to "starting and stopping" variations in the fuel bed within given limits.

Has CO a Good Point?

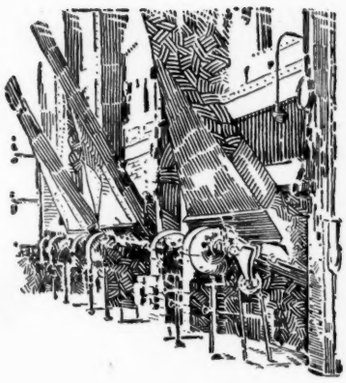
TO GIVE the devil his due is no more than fair, and CO is the "devil" of those who are striving for a commendable percentage of CO_2. Therefore, if there is anything good to say for CO, let it be said.

Does CO accomplish any good, and if so, to what extent does it offset the harm done? The answer to the first question is "Yes," and to the second, "Under ordinary conditions it offsets an appreciable but not a large portion of the harm." This small benefit arises from the fact that, for the same percentage of CO_2, an increase in CO indicates a smaller weight of flue gas per pound of coal burned, with a corresponding reduction in the sensible-heat loss. In spite of this, CO is still to be classed as decidedly undesirable.

For example, with an average coal, twelve per cent CO_2 and six hundred degrees flue temperature, the addition of one per cent of CO will waste four per cent in incomplete combustion, but reduce the sensible-heat loss by only one and one-half per cent.



Practical Ideas *from* Practical Men



Should Not the Engineer Decide What Boiler and Engine Equipment Is Necessary?

There are many managements of industrial plants who indicate by their allowance for any up-to-date equipment that they are inclined to believe that if a decade ago a man could gain a reputation as a renowned engineer with a boiler fitted only with a safety valve, steam gage and gageglass, then an engineer of today should be able to meet any requirements with but a little more.

When the price of coal was less than the drayage is now, or when firing with wood was a matter for discussion, CO_2 recorders were not considered necessary, but because they were not is one of the principal reason why the same grade of coal is costing us ten dollars a ton today.

The conscientious engineer loses interest in making a saving record, when his attempts are offset by poorly equipped plants. He knows the value of the heat units going up the stack or absorbed in some other non-producing agency, and when no attention is given to his suggestions to check such losses, he becomes a machine in the employ of the company rather than an efficient engineer, and any further efforts he might make are only such as are necessary for the wages received in place of being progressive as they would be if co-operation was offered him.

It is to be regretted that more of our plant managers have not been engineers or at least placed in a position where the causes and effects of modern appliances of the boiler and engine room could be more forcibly exhibited to them.

Privately owned plants are not so ready to disapprove of necessary additions as are municipal plants, perhaps because each director's longer association with the business shows him the possible savings, but with the municipal plant the directors are likely to be more or less politicians; and with a year or two in which to learn the needs of the plant, it is not surprising that the engineers' suggestions or desires are disregarded.

In power plants as well as in all other lines of business there are failures even when the outlook for the future has been remarkably good; and to the casual observer it is rather a mystery why such failures should occur. But when we know that there is possibly no other business more susceptible to failure than a power plant unless operated on modern plans, we can understand why plants attempting to operate with obselete equipment fail to meet the competition of the up-to-date ones.

Recording thermometers, draft gages, draft regulators and the other efficient equipments are merely watchmen to prevent the escape of useful costly material, yet we would not hesitate to pay good money for a watchman if these materials were as freely stolen from the doorway by a night prowler as they are through the chimney by an unchecked draft. And if our engineer in charge advised us that the night stealing was going on and that a watchman should be employed, we would at once take action on his suggestion. Then is there any reason why his suggestion for some money-saving appliance should not be as forthcoming as the night watchman?

We engineers are perhaps to blame for a good part of the slow action on the part of the managements when equipment is needed. We at some time have possibly made the mistake of suggesting a costly part that did not prove efficient, or we may not be capable of seeing the efficient action of an accessory that some competing plant is profiting by the use of.

Whatever the case may be, we must be on dependent terms with the management. There is little hope for co-operation or progressive work if we are distrusted. But with our dependency established and with a knowledge of the needs of a plant to make it efficient, it is a part of our duty to insist on the addition of the equipment and not to ignore its necessity merely because it is not depriving us of any part of our salary.

In other words, it should be you, the engineer, who should decide what boiler and engine equipment is necessary and do your part in assuming the responsibility for the plant's efficiency. G. G. McVICKER.

North Bend, Neb.

Practical Grouping of Boiler-Room Instruments

The illustration herewith shows a centrally located boiler-room instrument board in use in our plant. Grouping the instruments in this manner is, in our opinion, more practical and convenient than a separate panel installed at each boiler.

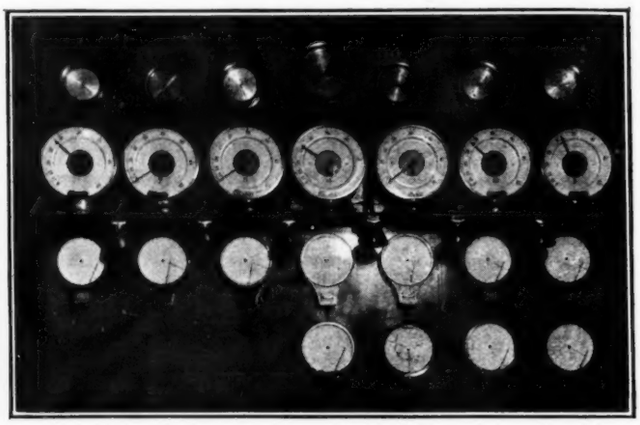
The instruments on the top row, reading from left to right, are: No. 1, pressure gage showing the first-stage pressure on the 7,500-kw. turbine; No. 2, pressure gage showing initial pressure of the 5,000-kw. turbine; No. 3, clock; No. 4, main steam header pressure; No. 5, boiler-feed water pressure; Nos. 6 and 7, pressure gages for two 2,000-kw. turbines.

The flow meters in the second row are of the indicating type, and each is connected to a 6,000-sq.ft. boiler. Directly below are thermometers for recording

the flue gas temperatures of the same boilers and these are arranged in the same relative order as the steam-flow meters.

In the lower row: No. 1 is a recording pressure gage on the main steam header; No. 2, pressure gage for recording the air pressure on the forced-draft air ducts to the stokers; No. 3, recording thermomenter on the boiler-feed water; No. 4, recording thermometer on the treating plant water.

In addition to the instruments shown on the board, each boiler is equipped with a draft gage for showing



GROUPING THE INSTRUMENTS ENABLES THE FIREMAN TO COMPARE READILY THE OPERATING CONDITIONS OF THE BOILERS

furnace draft, also a multiple gage for showing the air pressure on the different zones of the forced-draft chain-grate stokers.

The advantages of the centralized board are that the fireman can see at a glance the steam flow of each boiler, flue-gas temperatures, boiler-feed water pressure and temperature, steam pressure and air pressure, also the gages showing the turbine inlet or first-stage pressures enable the fireman to determine the load on the turbines.

The instruments being grouped, the firemen can make a comparison of the different boilers in service comparing steam flow and fiue-gas temperatures at a glance.

This grouping of instruments is of particular advantage when operating boilers at high rating; should the steam pressure drop, a glance at the board will readily show where the cause can be located.

CHARLES SEARMONTH, Chief Engineer,
El Paso, Tex. Power Station, Elec. Ry. Co.

Facilitating Oil-Switch Maintenance

To facilitate the work of removing, for inspection or repairs, the 11,000-volt oil-switch tanks in a large hydro-electric plant, the lifting truck shown in Figs. 1 and 2 was constructed in the machine shop of material readily available about the station. The truck is provided with three 9-in. wheels, the front wheel being swiveled to facilitate handling in close quarters. The frame is constructed of heavy channel iron, and two pieces of 2x¾-in. flat iron support the cable drum, which is operated by a ratchet lever. The diameter of the steel lifting cable is ⅜ in. An interior inspection of all oil-switch tanks is made at yearly intervals except when the duty imposed is exceptionally severe, in which case inspections are made more frequently.

When a switch tank is to be removed, the disconnectors are opened and tagged, the conductors connected to each of the six supporting bushings are grounded, and a safety card is issued by the operator. (See *Power*, Feb. 20, 1923, "Safeguarding Workmen in Hydro-Electric Stations.") After the oil-switch mechanism is placed in the open-neutral position, the contact rods are removed and the nuts are taken off two of the tank rods. A repair truck on which is mounted a small pump, is moved near the oil switch, and the tank is emptied through a metal hose inserted in the top bushing. After the repair truck is removed, the clamp at the bottom of the tank is loosened, the lifting truck is then moved into the compartment, Fig. 2, the lifting yoke is attached to the tank rods and the tank raised sufficiently to clear the supporting bushing. The truck, with the tank attached, is then wheeled to the repair shop. It has been found that by using the lifting truck one man can remove the largest tank more quickly and with greater ease than could two men using less efficient methods.

A four-wheeled repair truck occupying slightly greater floor space than the lifting truck has been constructed and is provided with a flat top that serves as a portable workbench. The rotary oil pump mounted on this truck is arranged for motor or manual operation, and a tank having sufficient capacity to contain the oil emptied from three of the largest switch tanks is placed beneath the pump. The used oil is drained from the truck tank for purifying, and a metal hose, which may be connected to the central switch-oil system at various points in the switchroom, is used to fill the tanks. A similar hose is used, in preference

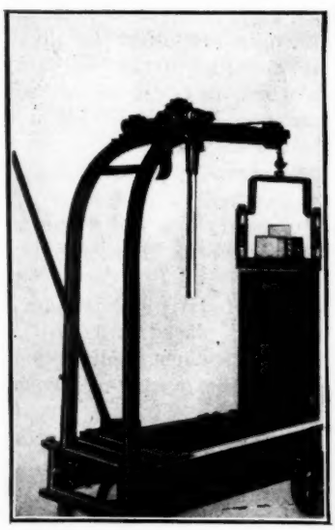


FIG. 1—OIL-SWITCH TANK SUPPORTED ON LIFTING TRUCK

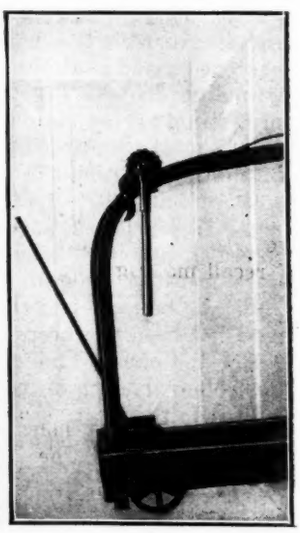


FIG. 2—LIFTING TRUCK IN OIL-SWITCH COMPARTMENT

to buckets, to replenish the oil in the high-voltage bushings.

The repair truck is equipped with a vise, and practically all of the tools required for the complete overhauling of an oil switch are kept in several drawers in this truck. All parts of the 11,000 volt oil switches that are accessible without dismantling are cleaned and inspected at monthly intervals, the repair truck greatly expediting this work, and that of complete overhauling.

Caribou, Calif. RALPH BROWN,
Great Western Power Co.

Comments from Readers

Drilled Holes in Pulley Prevent Belt Slippage

Referring to the article in the June 19 issue by G. A. Luers, entitled "Drilled Holes in Pulley Prevent Belt Slippage," I cannot say that I agree with him on his theory of why the belt ceased slipping after drilling holes in the pulley face.

In my opinion the reason the belt gripped better after drilling the holes was due rather to its gripping the edges of the holes and a possible suction effect caused by the holes. Of course, as he says, after the holes were drilled the belt pressure per unit of area was increased, but we might take a very narrow belt and make the pressure per unit of area twice that of the pressure in question and the belt might still slip.

It has always been my understanding that the more power you wished to transmit with the least amount of slippage, the wider the belt the better; in other words, not so much the pressure per unit of area, but rather the greatest area of surface contact between pulley and belt consistent with the load. HENRY B. DROWNE.

Cedar Manor, L. I., N. Y.

I am inclined to doubt the theory of Mr. Luers as to why the belt slippage ceased. He says: "The drilled holes diminish the area of contact of the belt. In consequence of this the belt pressure is increased for each unit of area, and as the pressure increases so does the coefficient of friction, resulting in increased effective pull."

It is true that the unit pressure is increased, but the coefficient of friction does not increase according to what I was taught in my physics course at college. I recall making a test on an ordinary brick. The brick was first laid on edge and pulled across a table by means of a dynamometer and the pull measured. It was then laid on the table on its flat side and the pull was measured again. The pull was exactly the same in each case. Therefore, in the case of the belt and pulley the drilling of the holes should make absolutely no difference, provided the bur was carefully removed as stated by Mr. Luers and provided the area was not reduced to so small an amount that there was a cutting action. So long as there is no cutting action, the pull, theoretically, is the same at all times regardless of the area.

It is quite probable that the reason why slip was stopped is that on drilling the holes air pockets were prevented between the pulley and the belt. The pulley is so shaped, having flanged edges, that air pockets might easily form without the holes. The drilling of holes on flat pulleys that possess no flange is common practice, and it usually helps.

It has been demonstrated by one pulley manufacturer that by building a groove in the pulley, which the manufacturer calls an "air groove," better results are obtained than where the groove is not used.

Newark, N. J. F. M. REILLY.

Straightening Copper Floats with the Aid of Air Pressure

I was interested in the article by R. A. Hall in the May 29 issue, on "Straightening Copper Floats with the Aid of Air Pressure," in which he advocates using a tire pump to put sufficient pressure in the float to bulge out the largest bends, then tapping with a light hammer around the edges of the smaller bends, gradually working to the center. This seems to me to be a rather dangerous and impractical method of straightening floats. Since the tensile strength and internal pressure are unknown, the float is liable to burst and possibly injure the workman.

Someone will say that if the float did burst, it would not do any harm. It may or may not. Air is a gas, and it causes vessels to explode just as steam or any other gas under pressure ,and a piece of copper, if torn free, may inflict serious injury.

I should call it bad practice to hammer on steam pipes or any other piece of equipment while it was carrying a pressure even though the pressure be known. Undoubtedly, many experiments of this nature that are performed in various plants are attained with more or less danger to the one performing them or those around him.

I suggest that if a float must be straightened by internal pressure, water be used. Even then I should not advise tapping the float with a hammer while the pressure is on. FRED E. CUPPER.

Jacksonville, Fla.

What Design of Furnace Is Best for Burning Mill Refuse?

Replying to the inquiry of Mr. McQuiddy in the May 8 issue as to the best type of furnace for burning mill refuse, I have used Dutch-oven furnaces with hollow blast grates. In my opinion they give all that is desired in making steam from mill refuse. The furnaces are extended for their full length in front of the boiler and are made flat on top. For a 2,000 sq.ft. boiler the furnace should be approximately 8 ft. long by 4 ft. wide and 4 ft. high above the grates, inside measurements. The bridge wall should be just back of the smoke box in a horizontal return-tubular boiler with the top of the wall about 14 in. from the boiler. The combustion chamber should slope from the bridge wall to the back of boiler and should be 3 ft. from bottom of boiler to combustion-chamber floor at the back end of the boiler. It should be paved with brick and fitted with a clean-out door, as the draft will carry ashes to the back and it will have to be cleaned out twice a week or oftener.

The refuse is fed to the furnace through one or more openings in the top of the oven about 14 in. in diameter. The fireman also controls the level and distributes the fuel to the corners of the grate of the fire through the opening instead of the furnace doors. The leveling

is best accomplished with a bar made from a 1-in. pipe long enough to reach all parts of the furnace.

The fire should be stirred as little as possible, as the fuel burns most from the top. As to the depth of fire, that depends on the dryness and size of the fuel, and this is best determined by a little experimenting.

It is good practice to have the injectors and feed pumps fitted with controlling valves both in the fireroom and up on the oven, so that they can be controlled from both places, from the top when the plant is running and from the fireroom floor when getting up steam. When firing up, a cover should be placed over the openings in the tops of the furnace and the firedoors used for feeding the furnace. Provision should be made adjacent to the boiler room for taking care of the surplus refuse from the mill. If the plant is operated only during the day, when shutting down at night all slides in the fuel pipes should be closed at least five minutes before stopping the engine. This is necessary to clean the conveyor of all dust and refuse as a precaution against fire.

The size of fan for supplying the air depends on the moisture in the fuel, the number of furnaces to be supplied and whether the fuel is all sawdust or sawdust and slabs or blocks from trimmings. If the fuel is partly dry and only about 50 per cent sawdust, only every other grate will need to be hollow, but if much dust or very fine trash is to be burned, it is the best to install all hollow grates. The method of driving the fan is in most cases best determined by a study of local conditions.

FRED E. CUPPER.

Jacksonville, Fla.

For the last twelve months I have had charge of a power plant burning waste, fuel, green sawdust, shavings, etc., making steam for operating a 300-kw. steam turbine, also for heating the factory and drying the manufactured product.

The steam plant consists of two 1,500-sq.ft. horizontal-tubular boilers equipped with Dutch oven furnaces. The fuel is fed partly by a dust collector system, but the heavier waste is conveyed by a carrier system.

We carry 130 lb. pressure and find it necessary to burn only the sawdust and shavings to produce the necessary steam, while the coarser waste is sold for fuel or piled up outside to be used when the machinery is not in operation.

CHARLES S. SCOTT.

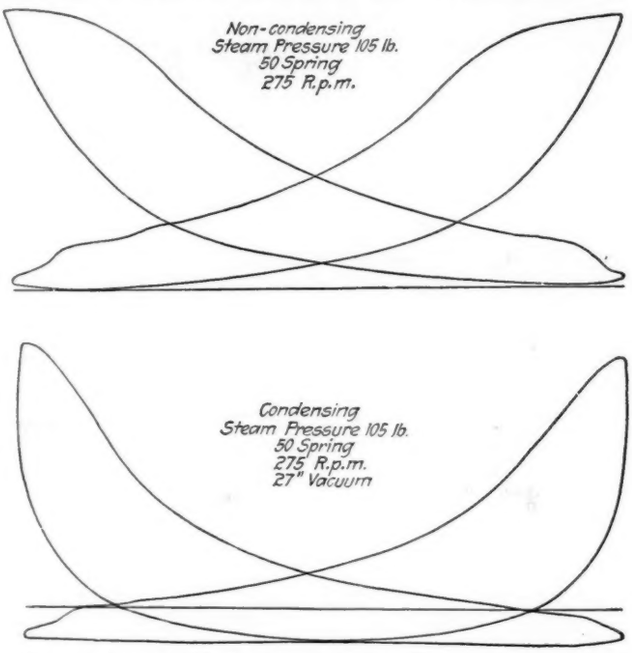
Oakland, Me.

A Unaflow Engine Without Auxiliary Exhaust Valves

In *Power*, Dec. 26, 1922, was published an article entitled "A Unaflow Engine Without Auxiliary Exhaust Valves." In the preface of this article the subject of clearance was discussed and the effects of large and small clearances in unaflow engines. The purpose of this article was to supply operating engineers and others interested in the Harrisburg dual clearance unaflow engine with reliable information for the adjustment of the valves. It clearly explains the purpose of the dual clearance and its effect in controlling the exhaust pressure during the return stroke of the piston. It also comments on certain changes that are reported to be necessary to the valve in case an engine is non-condensing.

We are rather late in taking exception to any misstatements that may have inadvertently crept into the article, but we feel that a proper explanation of the construction and manipulation of the engine, particularly in reference to condensing operation, is due to the numerous readers of *Power* and the manufacturers of the engine as well.

In designing the dual clearance unaflow engine for condensing operation, the cylinder clearance between the valve and piston is made of the least volume possible. The face of the piston is made straight and is machined and polished. The inner face of the cylinder head is also faced and polished and the piston brought



DIAGRAMS FROM A DUAL-CLEARANCE UNAFLOW ENGINE

as near to the heads at the ends of the stroke as safety of operation will permit.

For non-condensing operation larger clearance is required than when the engine is to run condensing, so to provide for this condition, pockets are cast, usually, on the sides of the cylinder near the end flanges. The volume of each end pocket, combined with the volume of the clearance between the valve and piston at the end of the stroke, is sufficient for non-condensing operation for the conditions used. These conditions may be atmospheric exhaust, or with back pressure above the atmosphere, the pocket being of such capacity as to allow the compression to carry to about the initial steam pressure in the cylinder.

Communication is established with the pocket and cylinder clearance by a port that can be opened or closed as may be required. This is usually accomplished by a valve held on its seat by a spring, which opens under the increasing back pressure in the cylinder should the vacuum break. The valve can then be opened by hand to give full area of the communicating port between the clearances and the engine continue to operate non-condensing or with back pressure greater than the atmosphere.

The action of the dual clearance goes on just the same whether the engine is running non-condensing or condensing, so here is where we must take exception to the third paragraph, which states that "in case the engine is to run condensing, the valve ends are spread

apart so that the dual clearance pipe is not uncovered by the valve. To change to non-condensing operation requires the readjustment of the valve, a matter of one or two hours' shutdown."

This is wrong, because no change to the valve is necessary and there is no interference with the functioning of the dual clearance with any change of conditions. To clear up this point indicator diagrams, taken from a 17x16 Harrisburg dual clearance unaflow engine, direct-connected to a centrifugal pump, operating at 275 revolutions with 105 lb. steam pressure at the throttle, are shown in the illustration.

These diagrams show both conditions of non-condensing and condensing operation. There was absolutely no change made to the valve; the diagrams were taken before and after the change from condensing to non-condensing, without stopping the engine.

This engine is doing service at the filtration plant of the city of Harrisburg, Pa., operating a Worthington pump, and this combination made the splendid record on the recent official test of 87,511,707 ft.-lb. duty per 1,000 lb. steam, exceeding the requirements of the specifications by 35.76 per cent.

The Harrisburg Foundry and Machine Works has recently brought out a pure Stumpf unaflow engine to be used entirely for condensing conditions and is not adaptable to non-condensing operations except in cases of emergency.

This engine is built with a special form of valve gear and with piston valves. On a recent test of this new development exceptional economy was obtained, but we will deal with this and its details of construction in another article.

BENJAMIN T. ALLEN, Chief Engineer,
Harrisburg Foundry and Machine Works.
Harrisburg, Pa.

What Caused the Freak CO_2 Readings?

Referring to the comments of S. S. Heide and E. C. Thompson in the June 19 issue on my article in the May 8 issue on "What Caused the Freak CO_2 Readings?" without doubt Mr. Thompson has hit on the proper answer to the question, and it remains to be shown just how far distillation will affect CO_2 readings with wood fuel. We are working on this line at present and may soon have some information available. The abnormal conditions are most pronounced with spruce as fuel, although this may be a coincidence.

I wish to assure Mr. Heide that the test methods used were not at fault. A sampling tube between the second and third rows of tubes in a horizontal water-tube boiler, when properly shielded from radiant heat, will not oxidize sufficiently to affect Orsat readings materially. Normal readings can be obtained from the same furnace and using the same apparatus when oil is being burned. Without doubt the difference between the first and last pass readings is due to setting leakage. This difference varies with the draft.

The titration method for determining CO_2 was that of R. B. Warder, which is sufficiently accurate to check Orsat determinations. To the cold solution containing phenolphthalein, hydrochloric acid is added and the liquid gently stirred with a glass rod. Decolorization takes place when all the hydroxide and half the carbonate are neutralized.

$$NaOH + HCl = NaCl + H_2O$$
$$Na_2CO_3 + HCl = NaCl + NaHCO_3$$

To the colorless solution methyl orange is added, and the solution is again titrated with acid until the other half of the carbonate is neutralized when the solution turns brownish red.

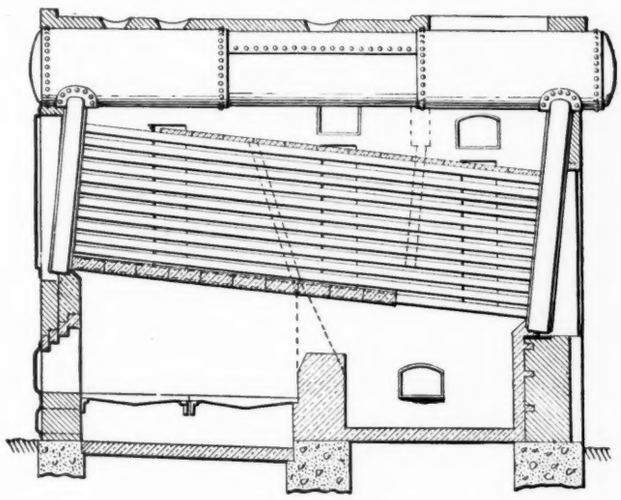
If the amount of acid used for the titration with phenolphthalein is represented by T, and that necessary for the titration with methyl orange by t, then $2tcc$ corresponds to the amount of carbonate, and T-t represents the amount of hydroxide. M. S. GEREND.

San Francisco, Calif.

Will Change from Vertical to Horizontal Baffling Increase Furnace Temperature?

We recently installed a 3,000-sq.ft. water-tube boiler with a bridge wall and baffle arranged as shown by the dotted lines in the illustration.

The boiler is hand-fired with barley and bird's-eye anthracite, the grates being of the pinhole type with 4 per cent air space and having an active surface of



SHOWS ORIGINAL AND PROPOSED TYPE OF BAFFLING

82 sq.ft. Forced draft is supplied by one 16-in. and one 20-in. blower. With the boiler setting arranged as shown with the vertical baffling, we find it impossible to get a furnace temperature above 2,000 deg., and consequently we obtain a low furnace efficiency.

We propose to rebaffle the boiler horizontally as shown, in which the lower baffle would serve as an ignition arch, but before going to this expense we should like to have the opinion of some readers of *Power* as to the probable increase in furnace temperature and boiler efficiency we would obtain by making the change. The lower horizontal baffle would be approximately 48 in. above the grates. F. WILLIAMS.

Scranton, Pa.

An average of 5.2 kw.-hr. per gallon of fuel oil for a period of two years is the record at the power plant of the Hershey Chocolate Corporation's plant in Cuba. This is a 6,000-kw. steam-turbine plant containing three 2,000-kw. units utilizing steam at 250 lb. and 200 deg. superheat. The four oil-fired water-tube boilers are of 5,000 sq.ft. heating surface each. While the figure given is the average for two years, the daily average has reached at times as high as 6.2 kilowatt-hours per gallon.

QUESTIONS AND ANSWERS

Conducted by Franklin VanWinkle

Cracks in Can Ice

What is the cause of cracking of the ice made in a can ice plant? We freeze at 10 to 13 deg. F., and the ice cracks before going to the dip tank. Under the same plant conditions we formerly did not have this trouble from city water. Would alum treatment of the water prevent cracks? F. S.

Ice cracks from freezing too rapidly. Sometimes dirt in the water will cause cracks and alum treatment is beneficial as a coagulant in the process of settling or filtration for clarifying the water. However, when cracks occur in ice made from fairly clean water, the trouble can be attributed to forcing the freezing.

Pump Valves for Handling Hot Water

We are running a 4½x2⅝x4-in. duplex pump for feeding a boiler operated at a maximum pressure of 100 lb. The temperature of the feed water handled by the pump ranges between 160 and 210 deg. F. The pump is fitted with 2-in. hard rubber valves, and considerable trouble is experienced with the valves' wearing down and leaking. Is it advisable or practical to have valves made of brass? M. A. M.

For pumping very hot water bronze valves or valves made of a special hard-rubber composition must be used. Undoubtedly, the proper kind of valves could be obtained of the manufacturers of the pump if informed of the conditions. Valves that are suitable for use with hot water are hard and inelastic and will not adapt themselves to inequalities of the valve seats. The leakage may be due to the use of valves that are warped, or the seats may be worn or imperfectly ground. The seats as well as the valves should be scraped or ground true to a surface plate.

Ventilating Air While Filling Boiler and Getting Up Steam

When filling an empty boiler and getting up steam, should not an air vent be left open, or should all outlets be closed? My master mechanic claims there is no necessity of venting the air and that it is just as good as steam. T. C. R.

While filling a boiler or getting up steam to atmospheric pressure, it is best to vent off the air through a gage cock, safety valve or other opening to the atmosphere; or the air may be discharged through an engine to help warm it up prior to starting. The disadvantages of leaving the air unvented are that in gradually raising the boiler pressure, most of the air is likely to gather in pockets and while remaining undischarged, it is productive of corrosion; or when the air is discharged into heating apparatus, its presence becomes a hindrance to circulation of steam and efficient operation.

Use of Dressing on Rubber Belts

Why cannot a belt dressing be used on rubber belting for increasing the driving power without injury to the belt? W. T.

Ordinary rubber belting is built up of alternate layers of canvas and rubber, with the faces of the belt overlaid by a layer of rubber. If a dressing is used on a belt of this kind, it is likely to cause greater adhesion of the surface rubber to the face of the pulleys than to the canvas and cause the belt layers to become stripped off. However, canvas-rubber belts that are made with a facing of canvas to go against the pulleys are less likely to become injured in this manner and can be improved in friction with the pulley by the use of a dressing, but the canvas facing should be impervious to ingredients of the dressing that may be injurious to the rubber used as a cementing material between the layers of canvas.

Type of Direct-Steam Condenser Pump

Why is not a duplex pump considered to be suitable for use as a vacuum pump in connection with a condenser? C. W. M.

For removing "air" from a condenser, the pump must compress the air and uncondensable gases to atmospheric pressure in order to discharge them to the atmosphere. The condenser pump is therefore more of an air compressor than a water pump, and for that purpose a duplex pump is unsuitable. As in the beginning of a compressor stroke there is no resistance except friction, one piston of a duplex pump would rapidly move forward and throw the valve of the opposite side before the latter, operating against a resistance, would have time to complete its stroke, resulting in a short stroke and very low efficiency. Hence, as condenser pumps single pumps are preferable, for in them the piston cannot reverse until it has completed its stroke and, with moderate piston speeds, they may be operated quietly and more effectively than duplex pumps.

Vacuum Referred to 30-in. Barometer

Having a vacuum-gage reading of 25 in. with 80-deg. room temperature and barometer 28 in. at the temperature of 70 deg. F., what would be the vacuum referred to a standard barometer of 30 inches? L. B.

The term "inches of vacuum" is used to express the number of inches of mercury column pressure less than the pressure of the atmosphere. The pressure of the atmosphere is variable, but the accepted standard is equal to the pressure exerted by 760 mm., or 29.921 in., of mercury at the temperature of 0 deg. C., or 32 deg. F., which is equal to a pressure of 14.696 lb. per sq.in.

(approximately 14.7 lb.); consequently 1 lb. per sq.in. corresponds to 2.036 in. of mercury column at the temperature of 32 deg. F., and 1 in. of mercury corresponds to a pressure of 0.4902 lb. per sq.in. If the mercury is at a higher temperature, its density will be less and a greater height of column will be required to balance a given pressure.

Vacuum-gage readings are generally expressed in inches of mercury referred to a standard 30-in. barometer. To retain the same standard of pressure, it is necessary to increase the standard temperature of 32 deg. F. to such a temperature as will increase the height of the barometer from 29.92 in. to 30 in. If the height is thus increased, the mean height would be 29.96 in., and as the coefficient of expansion of mercury is 0.000101, the mean change for each degree rise in temperature would be $29.96 \times 0.000101 = 0.003026$ in.; and as the total increase would be $30 - 29.92 = 0.08$ in., the number of degrees increase of temperature required would be $0.08 \div 0.003026 = 26.4$ deg. F. Adding this to 32 deg. for the 29.92-in. barometer gives $32 + 26.4 = 58.4$ deg. F. as the temperature for a 30-in. barometer equivalent to the standard 29.92-in. at 32 deg. F.

If the barometer and vacuum-gage readings are corrected to a temperature of 58.4 deg. F., the difference between the figures will give the absolute pressure in inches of mercury at 58.4 deg. F.; and if this difference is subtracted from 30 in., it will give the inches of vacuum referred to a standard barometer of 30 inches.

The mercury-column correction for any change in temperature may be closely approximated by the equation,

$$h = h_1[1 - 0.000101(t_1 - t)]$$

in which

h = Height of mercury column corrected to temperature t;
h_1 = Observed height of mercury column;
t_1 = Observed temperature of mercury column;
t = Temperature to which the column is to be referred.

A height of mercury in vacuum gage 25 in. and temperature of the mercury 80 deg. F., reduced to the standard temperature of 58.4 deg. F. would give

$$h = 25[1 - 0.000101(80 - 58.4)] = 24.95 \text{ in.}$$

and 28-in. barometer, temperature 70 deg. F., reduced to 58.4 deg. F., would be

$$h = 28[1 - 0.000101(70 - 58.4)] = 27.97 \text{ in.}$$

Hence, the absolute pressure in inches of mercury at the temperature 58.4 deg. F. would be $27.97 - 24.95 = 3.02$ in., and the vacuum referred to a standard 30-in. barometer $= 30 - 3.02 = 26.98$, or practically 27 inches.

Estimating Refrigerating Capacity

Our plant has brine-cooling tanks in which brine for circulation throughout our spray decks is returned and cooled by direct expansion coils submerged in these tanks. We carry a 15-lb. suction pressure on the ammonia line. What is the method of figuring the capacity of this equipment in tons of refrigeration? J. C. M.

To find the amount of tonnage used in cooling the brine circulated through the spray decks, it will be necessary to measure the number of gallons and, consequently, the number of pounds of brine circulated per minute. Then test the brine with a hydrometer or a salinometer, in order to find its density. The amount of heat removed from the brine will be the number of gallons circulated per minute, times the weight per gallon, times the specific heat of brine, times the difference in temperature between the incoming and outgoing brine. The weight of water per gallon is approximately 8⅓ lb., and this must be multiplied by the specific gravity of brine to find the number of pounds in a gallon of brine. It may be assumed that the specific gravity is 1.2 and that the specific heat of the brine is 0.7 B.t.u. per degree difference of temperature.

As an example, assume that the brine comes into the ammonia coils at 24 deg. F., and that you reduce it 4 deg., so the temperature going out is 20 deg. The temperature range is then 4 deg., and assuming that there is 100 gal. of brine circulated per minute and that by the hydrometer the specific gravity of the brine is 1.2, then the heat removed per minute would be the degrees range (4), times the number of gallons (100), times the weight in gallons (8⅓), times specific gravity of brine (1.2), times the specific heat of brine (0.7), which equals 2,800 B.t.u. per minute.

One ton of refrigeration is equivalent to the removal of 200 heat units each minute, and the tonnage in the example would be $2,800 \div 200$, which is equal to 14 tons of refrigeration.

Installation of Equipment for Utilization of Exhaust

The power required by our plant is developed by a steam turbine operating condensing, and heating required during half of the year is done with live steam. The turbine capacity is not sufficient when operated with back pressure necessary for the heating. Would it not be a good investment to install a generator set operated by a high-grade engine of sufficient power capacity for the load with 10 lb. back pressure to supply steam for the heating? N. W.

The greatest steam economy is obtained when all the steam supplied to the turbine or engine is used for power and heating, regardless of the type or economy of the turbine or engine. But for warming buildings with exhaust, the demand is variable, and when all of the exhaust cannot be utilized, more steam may be required to maintain the necessary back pressure than to operate under most economical conditions for the engine or turbine and supply live steam for the heating. For example, it would not pay to raise the back pressure on a large engine for the sake of heating a small room with part of the exhaust, as the additional steam required by the engine would be more than the live steam required to do the heating. The advantage of installing a separate engine and generator set cannot be generalized. The special conditions of the situation would determine whether better all around steam economy is to be obtained by the use of exhaust with back pressure, or do the heating with live steam and generate power with the best available engine or turbine economy; also taking into account whether the saving of steam that might be effected would warrant investment of an engine set to replace or supplement the power furnished by the turbine.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Easy Lessons in Engineering

Heat Values and Air Requirements of Fuels

When dealing with commercial solid and liquid fuels, there are only three combustible elements of any importance. These are carbon, hydrogen and sulphur, in order of their importance. We will first consider each by itself, starting with carbon. A good example of commercially pure carbon is oil coke. Suppose we take a pound of this and burn it. What happens? Twelve parts by weight of carbon unite with thirty-two parts of oxygen gas (from the air) to form 44 parts of carbon-dioxide gas. These proportions are worked out from the following chemical equation[1]:

$$C + O_2 \rightarrow CO_2$$

Parts by weight: $12 + 32 \rightarrow 44$

To get this to the basis of one pound of carbon, divide each item in the equation by 12, which gives:

1 lb. carbon + 2.67 lb. oxygen → 3.67 lb. carbon dioxide,

When this reaction takes place, each pound of carbon gives off heat amounting to 14,600 B.t.u. (British thermal units).

The oxygen required must come from the air which, by weight, consists of 23.1 per cent oxygen and 76.9 per cent nitrogen. The nitrogen is an inert (dead) gas that takes no chemical part in combustion except to slow it down by diluting the oxygen. The total weight of air used in any combustion process must be $\frac{100}{23.1} = 4.32$ times the weight of oxygen. So to burn one pound of carbon requires $2.67 \times 4.32 = 11.5$ lb. of air. Since no weight is lost in combustion, the total weight of the product obtained by burning one pound of carbon with the theoretical amount of air must be $1 + 11.5 = 12.5$ lb.

Next comes the gas hydrogen. The formula for its combustion is:

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

Parts by weight: $4 + 32 \rightarrow 36$

This reduces to the following:

1 lb. hydrogen + 8 lb. oxygen → 9 lb. water.

The heat given off by the combustion of one pound of hydrogen gas is 62,100 B.t.u. The weight of air required is $8 \times 4.32 = 34.6$ lb., and the total weight of combustion products from burning one pound of hydrogen with the theoretical amount of air is $1 + 34.6 = 35.6$ lb.

The formula for the combustion of sulphur is:

$$S + O_2 \rightarrow SO_2$$

Parts by weight: $32 + 32 \rightarrow 64$

The amount of air required to burn one pound will be $1 \times 4.32 = 4.32$ lb., and the weight of the combustion products, when using only the theoretical amount of air, will be $1 + 4.32 = 5.32$ lb. The heat given off will be 4,000 B.t.u.

The facts so far developed are summarized in the accompanying table:

HEAT VALUES AND WEIGHTS INVOLVED IN COMBUSTION

One Pound of	Burning to	Theoretical Weight Oxygen	Air	Products	Heat B.t.u.
Carbon (C).....	Carbon dioxide (CO_2)...	2.67	11.5	12.5	14,600
Hydrogen (H_2)..	Water (H_2O).....	8	34.6	35.6	62,100
Sulphur (S).....	Sulphur dioxide (SO_2)...	1	4.3	5.3	4,000

The figures as to heat values apply strictly only where the carbon, hydrogen and sulphur occur as separate elements. In coal some of the carbon (called "fixed carbon") is free, while another part is bound up with hydrogen in the "volatile combustible matter." Fuel oils consist almost entirely of hydrogen and carbon bound together in various chemical combinations called "hydrocarbons." When so bound, the heat value and air requirements are nearly the same as if they were uncombined.

Any oxygen present in the fuel has, however, an important effect in reducing the heating value and the amount of air required. We will not go far wrong if we assume that all the oxygen in the fuel is tied up with eight times its weight of hydrogen in the form of water. Therefore subtract from the total weight of hydrogen present one eighth the weight of oxygen to get the net weight of "free" hydrogen to be used in figuring the heating value and air requirements of the fuel.

Take the case of a coal with the following analysis as fired:

Element	Per Cent
Carbon.....	78.3
Hydrogen.....	3.1
Oxygen.....	5.7
Sulphur.....	1.5
Ash.....	11.4
Total.....	100.0

Taking one pound of fuel, the weight, in pounds, of each constituent will be one hundredth of its percentage as given in the analysis.

First figure the net weight of free hydrogen as follows:

Total hydrogen.....	0.031 lb.
Combined hydrogen = 0.057 ÷ 8 = ...	0.0071 lb.
Free hydrogen (difference).....	0.0239 lb.

Then the heating value and air required are computed as follows, carrying heats to the nearest 10 B.t.u. and air to nearest tenth of a pound:

Constituent	Weight	Heat Value per Lb.	Heat Value of Amount Present	Air per Lb.	Air for Amount Present
Carbon.....	0.783	14,600	11,430	11.5	9.0
Free hydrogen.....	0.0239	62,100	1,480	34.6	0.8
Sulphur.....	0.015	4,000	60	4.3	0.1
Total.....	.....	.....	12,970	....	9.9

Exactly the same method of figuring is used with fuel oil. The air required can be closely approximated by dividing the heating value by 1,300 for coal or 1,400 for fuel oil.

[1] See Easy Lessons in the June 26 and July 10 issues.

The Effect of Sulphur in Fuel on Flue-gas Composition and Computations

By C. HAROLD BERRY, M.M.E.*

With the ordinary methods of flue-gas analysis, sulphur dioxide in the flue-gas is counted (at least in part) as carbon dioxide. This article is a study of the effect of the sulphur content of the coal upon the flue-gas analysis and the possible error this may cause in computing the weight of dry flue-gas per pound of fuel. A factor to correct for the sulphur content is developed. Busy engineers who desire to learn the conclusions from this investigation without going through all the computations will find the results summarized in a short article on page 95 of this issue.

ALL fuels contain more or less sulphur, either free or in compounds, which burns to sulphur dioxide or trioxide, two gases which unite with water to form sulphurous and sulphuric acids respectively. These acids give rise to serious corrosion where they come in contact with unprotected metal.

Further, in any flue-gas-analysis apparatus, both sulphur dioxide and sulphur trioxide will appear as carbon dioxide. That is, if we had 12 per cent CO_2, and 2 per cent SO_2, any flue-gas analysis would give us a reading of 14 per cent CO_2, and only by comparatively elaborate chemical study could we detect even the presence of the SO_2, much less its amount.

Accordingly, it is not without value to raise two questions for study:

a. What is the relation between the sulphur content of the fuel and the percentage of sulphur-bearing gases in the flue gas?

b. What is the effect of these sulphur-bearing gases on the computations usually based on the flue-gas analysis?

For simplicity, we shall restrict our study to bituminous coal, since that is the most commonly used boiled fuel. Most bituminous coals approximate the following composition, in per cent by weight: Carbon, 60 to 80; hydrogen, 5; oxygen, 4 to 20; nitrogen, 1; sulphur, up to 5; ash, up to 20.

For the purpose of this study, let us assume a bituminous coal containing: Carbon, 70 per cent by weight; hydrogen, 5; oxygen, 7; nitrogen, 1; and a percentage of sulphur varying from 1 to 5. The ash content does not affect the flue-gas composition and may therefore be neglected. Let us further assume that only 10 per cent excess air is supplied and that all of the sulphur burns to sulphur dioxide.

TABLE I—COMPUTATION OF FLUE-GAS COMPOSITION

Element	Lb. per Lb. Coal	Lb. Oxygen Required	Product	Lb. per Lb. Coal	Mol. Weight	Relative Volume	Per Cent By Volume
C	0.70	1.867	CO_2	2.567	44	0.0583	16.55
H_2	0.05	0.400	H_2O	.....	..	.....	.....
S	0.01	0.010	SO_2	0.020	64	0.000313	0.089
O_2	0.07	.....	.....	.....	..	.....	.....
N_2	0.01	.....	.....	.....	..	.....	.....
Excess Oxygen			O_2	0.221	32	0.00691	1.96
Nitrogen from air and coal...			N_2	8.037	28	0.287	81.40
						0.352523	99.999

Gross O_2 required	2.277
O_2 in coal.....	0.070
Net O_2 required..	2.207
10% excess.....	0.221
O_2 supplied.....	2.428
N_2 supplied.....	8.027

The first step is to compute the composition of the flue gas resulting from perfect combustion, for coal containing 1 per cent sulphur. The computations are shown in Table I. We first compute the oxygen required for burning the several combustible elements, and from the total subtract the oxygen content of the coal, which gives us the theoretical supply. Adding 10 per cent to this gives the actual supply under the conditions assumed. From the known composition of air the nitrogen accompanying this is computed. The products of combustion include the excess oxygen and all the nitrogen from both air and coal. Water vapor is not included, since we desire the composition of the flue gases as ordinarily determined by analysis, which never indicates water vapor. The weights of the several products are divided by their respective molecular weights, giving relative volumes, which are reduced to percentages by volume, which is the usual manner of stating gas compositions.

Since we are interested in the quantity of SO_2, which is small, the data assumed are taken as exact, and the computations are carried to a number of significant figures which would be far from justified in any boiler test.

This computation is repeated for the same coal, but with the sulphur content increasing up to five per cent, and the flue gas compositions shown in Table II are obtained.

TABLE II—FLUE-GAS COMPOSITION FOR VARYING SULPHUR CONTENT OF FUEL

Percent Sulphur in Fuel	1	2	3	4	5
CO_2	16.55	16.50	16.39	16.31	16.23
SO_2	0.089	0.176	0.264	0.350	0.435
O_2	1.96	1.96	1.96	1.96	1.96
N_2	81.40	81.37	81.39	81.38	81.38
	99.999	100.006	100.004	100.000	100.005

The curve shown in Fig. 1 is plotted from the computed results of Table II. It appears that for sulphur contents below 5 per cent of the fuel, the percentage of SO_2 in the flue gas is proportional to the sulphur content of the fuel. The numerical values, of course, depend on the composition of the fuel and the excess air supplied. The curve is plotted for 10 per cent excess air. A smaller excess is hardly likely in practice. A larger excess will give lower percentages of SO_2 in the flue gas. Further, the values given herein were computed on the assumption that all the sulphur burns. Since sulphur compounds may, and probably do, appear in the furnace refuse (clinkers, etc.), these results represent maximum values.

The important thing to be noted is that, even for fuels relatively high in sulphur, the percentage of SO_2 in the flue gas is very low. This fact should not lead us to belittle the serious effects of sulphurous gases on exposed metal. A very low concentration of gases so corrosive in their action, especially in the presence of water, can and does result in extensive damage to metals with which they come in contact.

This completes our study of the first question before us.

In the taking of a flue-gas sample and its subsequent handling during analysis, the sample is constantly in contact with water, except in those very rare cases in which the confining liquid is mercury. Since SO_2 is highly soluble in water, there is at least a possibility that it has all been absorbed from the sample before the initial volume is measured. If this be true, SO_2 is in the same category with water vapor, which is not determinable by the usual analysis, and it must therefore be assumed as entirely absent from the "dry" gases as usually computed. In such a case there should be added to the "dry" gases the weight of SO_2 formed from the sulphur in the fuel, in just the same way that we add the water vapor formed by the combustion of the hydrogen of the fuel.

On the other hand, the partial pressure of SO_2 in the flue gas is very low, and, if the apparatus is properly prepared, the containing water will eventually become saturated with respect to all of the constituents of the flue-gas mixture. It is therefore possible that the sample may contain its full quota of SO_2 when the analysis begins. Let us assume that this is the case, and investigate the resulting errors.

In the analysis of flue gas the first operation after measuring the sample is the absorption of CO_2 by bringing

*The Detroit Edison Company.

the sample into intimate contact with caustic potash. This process immediately removes from the gas not only the CO_2, but also the SO_2. The resulting loss of volume, however, is always reported as CO_2. Thus this percentage is slightly high, depending upon the SO_2 content of the flue gas. In computing the weight of dry flue gas per pound of fuel we treat this percentage as pure CO_2, and apply to it the molecular weight of that gas, which i. 44. As a matter of fact, a small portion of this is really SO_2 whose molecular weight is 64, and for this reason the computed results are slightly in error. Our present problem is to determine, if possible, some simple means for cor..ecting the computed results for this error.

Let us first suppose that we have determined the composition of a flue gas by special methods adapted to the separation of SO_2 and CO_2, so that we have the gas analysis stated in terms of CO_2, SO_2, CO, O_2 and N_2, and let us further assume that the dry flue gas is known to contain no other constituents.

Derivation of the Formula

The total weight of dry gas per pound of fuel is computed on the assumption that all the carbon in the gas came from the fuel. The quantity of CO_2 mixed with the air supplied is usually so slight that this assumption may fairly be granted. The weight of dry gas per pound of carbon in this gas is computed by multiplying the percentage by volume of each constituent by the respective molecular weight of that constituent, and dividing the sum of these products by the sum of the products of the percentages by volume of the carbon-bearing constituents by 12 times the number of carbon atoms in the respective molecules. For the assumed gas analysis,

$$\left[\begin{matrix}\text{lb. dry gas per}\\ \text{lb. carbon in}\\ \text{dry gas}\end{matrix}\right] = \left[\frac{44CO_2 + 64SO_2 + 28CO + 32O_2 + 28N_2}{12\ (CO_2 + CO)}\right]$$

If we multiply this by the pounds of carbon in the gas, per pound of fuel, that is, by the pounds of carbon burned per pound of fuel, we shall have the pounds of dry gas per pound of fuel.

$$\left[\begin{matrix}\text{lb. dry gas}\\ \text{per lb. fuel}\end{matrix}\right] = \left[\frac{44CO_2 + 64SO_2 + 28CO + 32O_2 + 28N_2}{12\ (CO_2 + CO)}\right] \times \left[\begin{matrix}\text{lb. carbon}\\ \text{burned per}\\ \text{lb. fuel}\end{matrix}\right]$$

But, as we have seen, in practice we do not have a complete gas analysis. In particular, SO_2 shows as CO_2, so that the per cent of CO_2 shown is really [per cent CO_2 + per cent SO_2]. It is the effect of this error alone for which we wish to correct.

If we compute according to the foregoing formula, as is universally customary, we must assume SO_2 absent, since we have no means of knowing the SO_2 content of the gas, which appears only as a slight increment on the CO_2 figure. Thus we are in reality computing the gas weight from the following incorrect expression:

$$\left[\begin{matrix}\text{lb. dry gas}\\ \text{per lb.}\\ \text{fuel}\end{matrix}\right] = \left[\frac{44(CO_2 + SO_2) + 28CO + 32O_2 + 28N_2}{12\ [(CO_2 + SO_2) + CO]}\right] \times \left[\begin{matrix}\text{lb. carbon}\\ \text{burned per}\\ \text{lb. fuel}\end{matrix}\right]$$

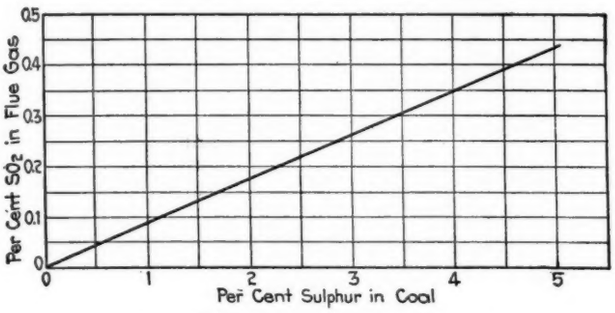
It is now proposed to find a factor, F, by which the first factor of this second expression may be multiplied in order to make it equal to the first expression, which is rigorously correct. The most direct method for doing this is to equate the correct expression to the product of the first factor of the incorrect expression multiplied by F, indicated as a letter, and then to solve for the value of F.

$$\left[\frac{44CO_2 + 64SO_2 + 28CO + 32O_2 + 28N_2}{12(CO_2 + CO)}\right] \times \left[\begin{matrix}\text{lb. carbon}\\ \text{burned per}\\ \text{lb. fuel}\end{matrix}\right] = \left[\frac{44(CO_2 + SO_2) + 28CO + 32O_2 + 28N_2}{12(CO_2 + SO_2 + CO)}\right] \times F$$

Solving for F, we have

$$F = \left[\frac{44CO_2 + 64SO_2 + 28CO + 32O_2 + 28N_2}{44(CO_2 + SO_2) + 28CO + 32O_2 + 28N_2}\right] \times \left[\frac{CO_2 + SO_2 + CO}{CO_2 + CO}\right] \times \left[\begin{matrix}\text{lb. carbon}\\ \text{burned}\\ \text{per lb. coal}\end{matrix}\right]$$

In order to reduce this expression to a less cumbersome form, we shall find it necessary to introduce certain approximations. In doing this, we must be careful not to introduce errors greater than that for which we wish to correct.



MAXIMUM PERCENTAGE OF SO_2

In the first place, the first expression in brackets differs but little from unity. The sum of terms,

$$[44CO_2 + 28CO + 32O_2 + 28N_2],$$

which occurs in both numerator and denominator, will be of the order of 2,800 or 3,000, since the value of N_2 will not differ greatly from 80, and CO_2 and O_2 may each fairly be taken as equal to 10. As we have already seen, the percentage of SO_2 will hardly exceed one with any commercial coal, and will, in most cases, be but a small fraction of this. For the more usual fuels, 0.5 per cent may fairly be taken as the maximum probable SO_2 percentage, which gives

$$\frac{3,032}{3,022} = 1.00331$$

Thus we may take this fraction as equal to unity, confident that in so doing we are introducing errors less than half of one per cent in the weight of dry flue gas, and that in most cases the error introduced is much less than this.

This leaves us

$$F = \left[\frac{CO_2 + SO_2 + CO}{CO_2 + CO}\right] \times \left[\begin{matrix}\text{lb. carbon}\\ \text{burned per}\\ \text{lb. coal}\end{matrix}\right] = \left[1 + \frac{SO_2}{CO_2 + CO}\right] \times \left[\begin{matrix}\text{lb. carbon}\\ \text{burned per}\\ \text{lb. coal}\end{matrix}\right]$$

From Avogadro's Law we know that the relative volumes of sulphur-bearing and carbon-bearing gases are proportional to the relative numbers of sulphur and carbon atoms present in the gas, so long as each molecule of the constituents in question contains only one atom of one of these elements, which is the case here. The relative numbers of sulphur and carbon atoms present in the gas may be computed by dividing the relative weights of these elements

burned by the respective atomic weights (carbon 12, sulphur 32). This gives us

$$\left[\frac{SO_2}{CO_2 + CO}\right] = \frac{\left[\dfrac{\text{lb. sulphur burned per lb. coal}}{32}\right]}{\left[\dfrac{\text{lb. carbon burned per lb. coal}}{12}\right]} = \frac{3}{8}\left[\frac{\text{lb. sulphur burned per lb. coal}}{\text{lb. carbon burned per lb. coal}}\right]$$

from which we write directly

$$F = \left[1 + \frac{3}{8}\left(\frac{\text{S burned}}{\text{C burned}}\right)\right] \times \left[\text{lb. carbon burned per lb. coal}\right]$$

$$= \left[\left(\text{lb. carbon burned per lb. coal}\right) + \frac{3}{8}\left(\text{lb. sulphur burned per lb. coal}\right)\right]$$

This expression is simple enough for ordinary use, so that we may incorporate it in the formula for the weight of dry flue gases, which becomes

$$\left[\text{lb. dry gas per lb. fuel}\right] = \left[\frac{44(CO_2 + SO_2) + 28CO + 32O_2 + 28N_2}{12\,[(CO_2 + SO_2) + CO]}\right] \times \left\{\left[\text{lb. carbon burned per lb. fuel}\right] + \frac{3}{8}\left[\text{sulphur burned per lb. fuel}\right]\right\}$$

In the application of this formula the weight of carbon burned per pound of fuel is easily determined, at least conventionally, by well-known methods of computation. The weight of sulphur burned per pound of fuel is quite another matter. Unless unusual methods of testing are adopted, we have no data on which to determine this quantity, and accordingly it would seem that the best we can do is to assume that all the sulphur present in the coal is burned.

It must not be overlooked that this formula is an approximation, in that we have deliberately neglected a factor which may differ from unity by something less than one-half of one per cent (usually very much less than this), and further in that we have assumed that there are present no hydrocarbons containing more than one atom of carbon per molecule. Neither of these assumptions is far from the truth, and neither of them can be avoided without the introduction of excessive complication in the computation of such results.

Inasmuch as the SO_2 content of flue gas will always be small, often well within the limits of error of the gas analysis itself, and inasmuch as it is not at all certain that this SO_2 all appears as CO_2, and inasmuch as we are not justified in assuming in all cases that all the sulphur in the fuel burns, it is questionable whether we are justified in making any "correction" for sulphur, and it seems certain that we are not justified in splitting hairs when it comes to precise refinements. Accordingly, the formula developed in the foregoing may be taken as good enough for all ordinary testing work. If greater accuracy is necessary, efforts had best be made in the direction of determining the actual SO_2 content of the gas rather than in finding corrections for the absence of this determination.

What is the magnitude of the correction formulated above? In other words, what is the difference between the quantity

$$\left[\text{lb. of carbon burned per. lb. fuel}\right]$$

and the quantity

$$\left[\left(\text{lb. carbon burned per. lb. fuel}\right) + \frac{3}{8}\left(\text{lb. sulphur burned per. lb. fuel}\right)\right] ?$$

If the carbon content of the coal is 70 per cent and the sulphur 5 per cent, the respective quantities burned cannot exceed these percentages. If combustion were complete, the value of the second quantity above would be

$$0.70 + \tfrac{3}{8} \times 0.05 = 0.71875$$

The difference between this and 0.70 is 0.01875, which is 2.68 per cent of 0.70. That is, for fuels high in sulphur this correctio will approach 3 per cent. For fuels containing only 1 or 2 per cent of sulphur the correction will be less than 1 per cent and may as well be neglected.

What of computations other than that for the total weight of dry flue gases per pound of fuel? For example, in computing the heat losses due to incomplete combustion, we desire to know the weight per pound of fuel of the unburned combustibles present in the flue gas, such as CO and H_2. It can readily be shown by precisely the method followed above, that the proper formulation is of the type

$$\left[\frac{28CO}{12\,[(CO_2 + SO_2) + CO]}\right] \times \left[\left(\text{lb. C burned per lb. fuel}\right) + \frac{3}{8}\left(\text{lb. S burned per lb. fuel}\right)\right]$$

In this case the correction is slightly more accurate than in the computation for total weight of dry gases, in that in the former case we neglected the factor

$$\left[\frac{44CO_2 + 64SO_2 + 28CO + 32O_2 + 28N_2}{44(CO_2 + SO_2) + 28CO + 32O_2 + 28N_2}\right]$$

which does not appear in this case.

There remains but one question—What happens to this correction if the flue gas contains hydrocarbons? For example assume that the flue gas, in addition to the composition assumed above, contains methane, CH_4. The value of the factor F reduces to

$$F' = \left[\frac{CO_2 + SO_2 + CO + CH_4}{CO_2 + CO + CH_4}\right] \times \left[\text{lb. carbon burned per lb. coal}\right]$$

$$= \left[1 + \frac{SO_2}{CO_2 + CO + CH_4}\right] \times \left[\text{lb. carbon burned per lb. coal}\right]$$

Inasmuch as CH_4 contains only one atom of carbon pe molecule, the correction reduces to exactly the form already derived, and the weight of dry gases per pound of fuel becomes

$$\left[\text{lb. dry gas per lb. fuel}\right] = \frac{44\,(CO_2 + SO_2) + 28CO + 16CH_4 + 2H_2 + 32O_2 + 28N_2}{12[(CO_2 + SO_2) + CO + CH_4]} \left\{\left[\text{lb. carbon burned per lb. fuel}\right] + \frac{3}{8}\left[\text{lb. sulphur burned per lb. fuel}\right]\right\}$$

If there were present hydrocarbons containing more than one atom of carbon per molecule, such as C_2H_2 or C_2H_6, the correction would not reduce to any simple form, but the possibility of such hydrocarbons appearing in appreciable quantities is so remote as to require no consideration.

As already stated, the purposes of this investigation and the conclusions reached have been briefly outlined on page 55. The information there given should meet the needs of engineers who lack the time to follow the derivations in the present article.

Hyperbo Electric Flow Meter

Because of space limitations it was necessary to make a last-minute cut in the description of the recording mechanism of the Hyperbo Electric Flow Meter on page 1025 of the June 26 issue. In condensing the fifth paragraph on this page, an error was made in the last line. This should read: "A four-throw cam on the mainshaft insures the repetition of this balancing operation every 1¼ seconds."

New Information on the Fatigue of Metals

Since 1919 the Engineering Experiment Station of the University of Illinois has carried on, in co-operation with the National Research Council and the General Electric Co. an extensive series of experiments on the fatigue of metals. The first report, contained in Bulletin No. 124 of the Experiment Station, was abstracted in the Dec. 13, 1921, issue of *Power*. The work done since that time is described in a new bulletin, No. 136, which contains nearly one hundred

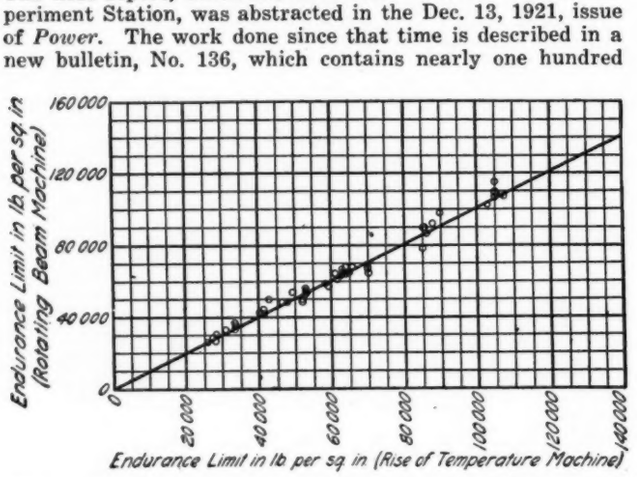


FIG. 1—CORRELATION OF ENDURANCE LIMIT BY ROTATING-BEAM TESTS AND BY RISE-OF-TEMPERATURE TESTS

pages of test results and conclusions of the greatest value to manufacturers of machinery in which rotating or other moving parts are subjected to repeated changes in stress.

Among the conclusions drawn from the work to date the following are of outstanding importance:

It has been fairly well established that ferrous wrought metals have a definite endurance limit, the endurance limit being defined as the unit stress below which a metal is capable of withstanding an indefinitely large number of complete reversals of stress.

This endurance limit may be determined with a fair degree of accuracy by a short-time test in which the rise of temperature under reversed stress is measured.

The endurance limit seems to be correlated with the

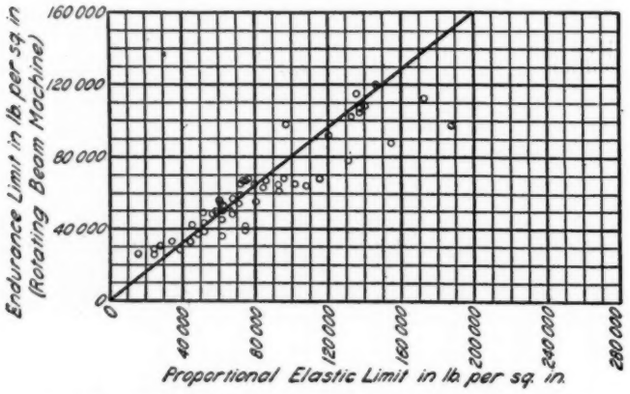


FIG. 2—CORRELATION OF ENDURANCE LIMIT WITH PROPORTIONAL ELASTIC LIMIT

ultimate tensile strength, with the Brinell hardness number, and in a much smaller degree with the yield point and the proportional elastic limit. No correlation was found between the endurance limit and the ductility, the result of the Charpy impact tests of notched bars, or repeated impact tests.

The effect of speed of reversal of stress on the determination of the endurance limit seems to be slight.

The results of the tests of specimens with various temperatures of "draw," after oil quenching, indicate that for carbon-steel specimens tested, neither the ultimate tensile strength, the endurance limit for flexure nor the ductibility was appreciably affected by draws at a temperature lower than 600 deg. F. For nickel-steel specimens for draws up to 400 deg. F. the ultimate tensile strength and the endurance limit for flexure diminished slightly, while the ductility increased a little. For draws at higher temperatures the changes in values of strength and ductility were more marked, the ultimate tensile strength and endurance limit decreasing, and the ductility increasing. Whatever advantages may be gained by draws below about 600 deg. F., such as relief from internal stress and increased machinability, may be obtained with but little, if any, sacrifice of tensile strength or of endurance under flexure.

The results obtained with specimens subjected to severe tensile overstress before being tested in reversed bending indicate that a few applications of stress, well above the proportional elastic limit of the metal, lowered the endurance limit under subsequent reversed stress, the endurance being diminished by 22.9 per cent of its original value for one set of specimens.

If a specimen or machine part is subjected to cycles of repeated bending stress higher than the proportional elastic limit of the metal, the tests indicate that there may result a failure by excessive distortion of the specimen or the machine part. The endurance limit under repeated bending stress should, then, never be considered as higher than the proportional elastic limit of the metal.

Fig. 1 shows the close correlation that exists between the endurance limit as determined by the rotating-beam machine used in the test, and the same limit as determined quickly by the rise-of-temperature machine. While the correlation between the endurance limit and the other

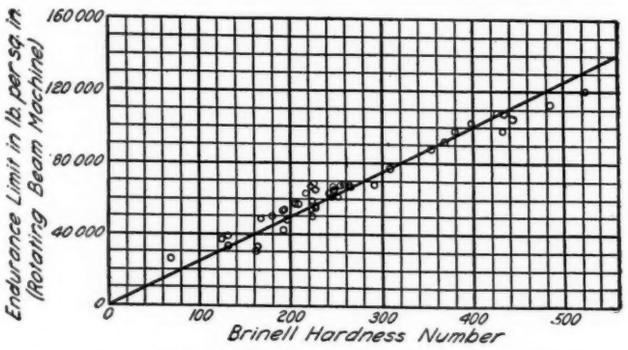


FIG. 3—CORRELATION OF ENDURANCE LIMIT WITH BRINELL HARDNESS

properties is not so close, Figs. 2 and 3 show that there is a fairly definite relation between the endurance limit and the elastic limit and Brinell hardness respectively. Similar curves can be drawn for the yield point and ultimate tensile strength.

How a Leather Belt Transmits Power*

The act of putting the belt on the pulleys under tension causes it to stretch. The stretch is partly elastic and partly inelastic.

The elastic part of the stretch gives the belt a tendency to contract again, thus causing grip or traction on the pulleys which is necessary for transmission of power, and causing also pull on the journals, which means journal-friction with loss of power.

The inelastic part of the stretch is due to a slippage of the leather fibers on each other, and this slip is not recovered when the tension is removed. This means slight internal friction, and some slight loss of energy, which appears as heat in the belt.

When a belt is started running, but without load, the new features are: (1) the effect of stiffness of belt and (2) the effect of centrifugal force.

The stiffness of a belt causes internal friction at all

*From a paper prepared for the Leather Belting Exchange.

points where the belt bends or unbends. This generates heat and means some lost energy.

Centrifugal force acts on every particle of leather that is moving in a curved path, as around the pulleys or in the sag. This causes centrifugal tension in the whole belt.

Every particle of belt while going around the arc of a pulley has a definite tendency, due to centrifugal force, to fly away from the pulley and thus lessen the grip or traction of the belt on the pulley. It is necessary to have a certain tension on the belt to get this tractive effect, which is caused by the grip of the leather on the pulley. Owing to centrifugal force, it is also necessary, especially at high speeds, to increase the initial tension sufficiently to overcome this tendency of the belt to fly away from the pulley.

The centrifugal tension is added to the tension already in the belt, causing it to stretch more and to stand off from the pulleys. This has the effect of not only reducing the traction on the pulleys, but also reducing journal friction.

The amount of centrifugal tension depends on the weight per foot of the belt; doubling the weight per foot doubles the centrifugal tension. It also depends on the speed of the belt, and is proportional to the square of the speed;

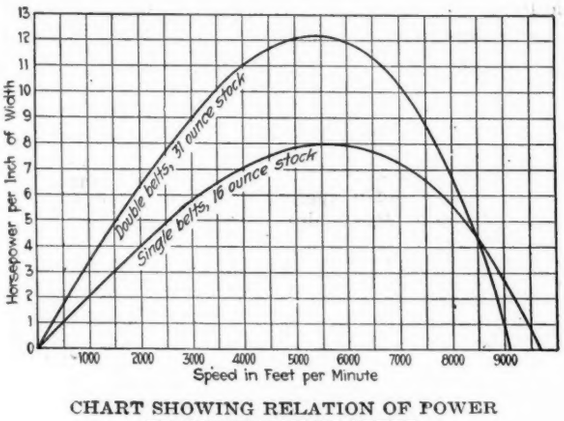


CHART SHOWING RELATION OF POWER TRANSMISSION TO SPEED

doubling the speed multiplies the centrifugal tension four times.

At extreme speeds the centrifugal tension may become equal to or greater than the original tension, in which case the belt may be seen to stand off from the pulleys, touching them only at the top where its weight is supported. Under these conditions little or no power can be transmitted.

The illustration shows two theoretical curves, based upon data secured from a 16-oz. belt running under certain conditions of tension and speed. It illustrates the fact that if no changes are made in the tension except those produced by centrifugal force, at the higher speeds the power begins to fall off rapidly and that at extremely high speed, such as 8,000 or 9,000 ft. per min., no power would be transmitted. It would, of course, be possible to transmit some power at even these excessive speeds by very materially increasing the initial tension upon the belt.

When a load is applied the important additional factors are changes in length, creep and slip.

When transmitting power, there must be a tight and a slack side. A given section of belt is stretched more on the tight side than on the slack side. Therefore this section is longer when passing onto the driving pulley than when passing off. The reverse is true at the driven pulley. The change in length must take place while on the pulleys and is called creep.

On account of the elasticity of leather there is actually a different speed in the particles of belt traveling on the tight side from that which exists on the slack side. We have actually observed a difference of over 1 per cent between the speed of the slack and tight sides of the belt near the point where the belt leaves the pulleys. The actual amount of creep observed in a belt running under light load is small, and at light loads the particles are probably only slipping upon the surface of the two pulleys for a few degrees of the arc of contact on the pulley.

The region in which creep takes place probably begins at the point where the belt leaves the pulley, and extends backward as the load is increased, finally covering the entire arc of contact. At this point slip begins; that is, in addition to the creep, the belt as a whole begins to slip on the pulley all around the arc of contact. Speed of slip increases with increasing load, and when excessive, the belt may run off the pulley.

The two factors of power are speed, and pulley traction or grip.

You can transmit more power by running the belt faster. Except for the centrifugal effect, the power would be proportional to the speed—twice the speed would give twice the power. But since the unfavorable effect of centrifugal action is proportional to the square of the speed, this soon overbalances the other, and beyond a certain point power begins to decrease as the speed increases.

Since the centrifugal effect depends on the weight of the belt, it is advantageous to use the lightest stock and the thinnest and narrowest belt compatible with sufficient strength and reasonably long life.

The second factor of power is grip, or traction. This is the same as the frictional force of the pulley on the belt, and is equal to the difference of tension between tight and slack sides. The friction does not depend on the width of the belt, but does involve: (*a*) Character of surface of belt —kind of leather, tanning, currying; (*b*) pulley surface —iron, steel, wood, paper, etc.; (*c*) tension of belt, because this produces pressure of belt on pulley—the greater the pressure, the greater the traction; (*d*) arc of contact—the friction increases very rapidly with the arc of contact, so that a small increase in arc gives a large increase of friction; (*e*) the speed of creep and slip—friction between belt and pulley increases as the speed of slip or creep increases. In other words, the grip of the belt on the pulley is better when slipping, and the faster the slip the better the grip, up to a certan point. Evidently, this must be true or else, after slip begins, you could not get more power—the belt would simply slip faster.

The coefficient of friction and slip increase with the load, also the coefficient of friction increases as the slip (or creep) increases.

Hardness of American Water Supplies

Writing in the June 28 issue of *Engineering News-Record*, W. D. Collins, of the United States Geological Survey, gave some interesting information in regard to the hardness of municipal water supplies in various sections of this country. The hardness in all cases was expressed in parts per million (p.p.m.). These figures can be reduced to the unit of grains per U. S. gallon by dividing by 17. Mr. Collins' remarks follow:

Thirty-nine million people living in 307 cities use the water supplies on which analytical data are reported in the forthcoming Water Supply Paper 496 now nearly ready for distribution, on which the following statements are based.

The average hardness of the water used by those in the 307 cities considered is 99 p.p.m., which is nearly the same as the average hardness of the water from the Detroit supply. The average hardness of water from surface supplies used by about 35,000,000 people is 85 p.p.m. and the average for the ground water supplies used by about 4,000,000 is 225 p.p.m. The average hardness of water from the public supplies of large cities is less than 55 p.p.m. in the New England states, in the other states except Florida along the Atlantic Ocean and the Gulf of Mexico east of Texas and in Washington and Oregon. From large public supplies in Idaho, Kentucky, Montana, Nevada, Pennsylvania, Tennessee and West Virginia, it is from 56 to 100 p.p.m. In some of these states the larger supplies are from sources that furnish much softer water than can be obtained generally in the state. In the states not named the average hardness is from 100 to 500 p.p.m. About 3,500,000 people use water from Lake Michigan which has a hardness of about 130 p.p.m. The water is softened at several cities in the Mississippi drainage basin. Throughout this area and in the Southwest the hardness of the water of public supplies is generally between 250 and 350 p.p.m. except in the cities using water from the Great Lakes or from mountain streams and in the cities where the public supply is softened

News in the Field of Power

Dominion Fuel Board's 1923 Interim Report

From 1912 to 1922 Canada's bill for imported coal exceeded the sum of $580,000,000. In 1922, during the coal strike in the United States, Canada, awakening to the need of definitely taking stock of her fuel resources, created the Dominion Fuel Board as a start toward the solution of the problem.

The dependence upon the United States and the uncertainty of this single source of supply had been demonstrated again and again. The coal strike of 1902-03 and the consequent suffering of the people in their homes and the closing of the factories contributed to the rapidity of the hydro-electric power movement. Since that time inconveniences have been caused by freight embargoes and other transportation tie-ups in the United States and during the war the pinch of shortage was again felt and fuel rationing by government authority instituted. The strike of the coal miners in the United States in 1922, coming with the railway shopmen's strike, was the last painful incident that impressed upon the Canadians the danger of having to rely on a single, although friendly, country for such a vital necessity.

The salient points of the Canadian fuel problem are well known. There are ample supplies of coal, but they are at such distances from the manufacturing and industrial centers that it is easier and cheaper to import from the United States than to transport from Canadian mine to Canadian consumer.

The report takes up these various angles of the problem and states that although electricity for house heating is at present impractical, its use for industrial and transportation purposes sets free large amounts of coal for heating. Twenty-seven million tons of coal would be necessary to produce the horsepower now developed annually by water power in Canada.

In the period 1916-21 Canada exported, on the average, to the United States hydro-electric power equal to over 43 per cent of all the anthracite imported, while exports of both coal and hydro-electric power were over 68 per cent of the anthracite imports. The import of all classes of coal from the United States into Canada is 3 per cent of the total United States production, the import of anthracite is 2 per cent.

Canada has large and strategically situated peat resources which total an area estimated at 37,000 square miles, comprising principally 46 bogs in Ontario, 27 in Quebec, 7 in Manitoba and 27 in the Maritime Provinces. Experiments conducted by the government have produced a high-grade auxiliary fuel from peat, which is satisfactory for domestic furnaces during the spring and autumn months, although it is twice as bulky as anthracite.

On account of the large reserves, the proximity to points of consumption and the well-organized transportation systems, the possibility of coking United States bituminous coal for domestic heating at points not capable of being served by Canadian fuel is held up as a partial solution of the problem.

Allberta coal, which was forced upon the people of Manitoba during the war, has remained in favor and to-day has practically driven the United States anthracite from the field, so that last year approximately 75 per cent of the coal used for domestic purposes there was mined in Canada.

I. C. C. to Investigate Freight Rates on Coal

THE Interstate Commerce Commission, acting upon the suggestions contained in the report of the President's Coal Commission, ordered an investigation into railroad rates, charges, classifications, regulations and practices governing the transportation of coal in the United States and into foreign commerce.

A paragraph of the Coal Commission's report on the anthracite industry stated that the rates on anthracite apparently constituted a very large proportion of the consumer's cost of the commodity. The level of such rates was said to be possibly too high to be justifiable.

The Interstate Commerce Commission, complying with the recommendation, has served notice on all common carries that it will seek evidence on the subject, taking up the rates on cargo and bunker coal at ocean ports and rates on boat lines over the Great Lakes.

Horsepower of a Horse to Be Determined

The actual horsepower of a horse will be determined at the Iowa State Fair this year where scientific tests will be made.

A specially constructed wagon has been designed for the tests by the engineering department of the Iowa State College. By means of gears and a hydraulic pump driven from the wheels, it will be possible to put on any predetermined load and maintain uniform load resistance from the test wagon, whether it travels on a level or up or down hill. The teams probably will be required to pull a six-horsepower load to enter, the load to be increased by two horsepower on each successive trial until the maximum is reached.

Horsepower has been a standard of power measurement for years, but little research work in the hauling power of horses and mules has been carried on scientifically because of the difficulty in providing a uniform tractive resistance.

To Try Pulverized Fuel

The United Electric Light and Power Co. is arranging at its Sherman Creek station, to use fuel pulverized by a Simplex unit, with a capacity of 8,000 lb. per hour under a specially built boiler.

1250-Hp. Diesel Added to Steam Plant

The Municipal Light Plant of Ponca City, Okla., has been using four-valve steam engines and horizontal tubular boilers for a number of years. Even though boiler oil as well as natural gas was comparatively cheap, the town being in the oil fields, recently the officials purchased a 1,230-hp. Nordberg vertical two-stroke-cycle Diesel to meet the growing power demand.

Pacific Gas & Electric Co. to Build Pit River No. 3 Plant

The Pacific Gas & Electric Co. has been authorized by the Railroad Commission of California to spend $12,312,600 through its construction division, the Mt. Shasta Power Corp., for hydro-electric development on the Pit River in northern California. Construction work is already under way on the new plant to be known as Pit River No. 3. The work involves boring a 19 ft. water pressure tunnel 22,700 ft. long which will have a capacity of 3,000 sec.-ft. Three penstocks will deliver water through the power house under a head of 313 ft. developing 108,000 hp.

Another Diesel Light Plant on Long Island

The East Hampton, Long Island, N. Y., Electric Light and Power Co. has placed an order with the McIntosh & Seymour Corporation for a 300-hp. Diesel engine-generator unit. This company has found the present steam-engine plant inadequate for the lighting needs of the rapidly growing town, and in view of the lower fuel costs of the oil engine it decided to install one such unit and if the results are as expected will install a second unit.

Executive Board American Engineering Council Meets

Developing participation by engineers in public affairs was strongly evident at the last meeting, held in St. Paul, in June, of the Executive Board of the American Engineering Council of the Federated American Engineering Societies. General round table discussion revealed that local groups are taking a constructive part in solving community problems relating to traffic, smoke abatement, water supply, city planning, state and municipal legislation and related engineering subjects.

The Committee on Storage of Coal reported that its plans had been perfected and that the survey was well under way. Subcommittees are being formed in some eighty centers. Each member society has been requested to designate a member on each subcommittee. The response to these requests has been gratifying. Dean Perley F. Walker of the University of Kansas, Lawrence, has been authorized by the committee to devote all his time for the next few months to the work. He will visit the various centers and assist the subcommittees in organizing and executing their respective tasks.

The committee appointed some months ago to prepare a proposed registration law for engineers submitted a draft of a proposed bill, which, after a lengthy discussion, Colonel Doty, of St. Paul, chairman of the Minnesota Board of Examiners, contributing constructive criticism, the committee was instructed to rewrite and report at the next meeting.

A request was received from the Cleveland Engineering Society that the Federation support the movement for the appointment by Congress of a technical commission to make a thorough study of the engineering and economic phases of the proposed St. Lawrence waterway before making any definite decision regarding the project. The Executive Board referred the matter to the Committee on Public Affairs for an exhaustive study and report.

The Board accepted an invitation from the Chamber of Commerce of Rochester, N. Y., to hold its next meeting there during the first two weeks in October, the date to be fixed by the Committee on Procedure.

New Publications

Lighting Circuits and Switches. By Terrell Croft. Published by McGraw-Hill Book Co., Inc., New York, 1923. Cloth; 5½x8 in.; 472 pages; 557 illustrations. Price, $3.

The material in this book relates almost wholly to electric-lighting circuits for interior applications, operating at low potentials. It is divided into 9 divisions: Circuit and switch nomenclature; lighting-switch construction; underwriters' requirements; single- and multi-pole switch circuits; three- and four-way switches; master or emergency circuits: electrolier and heater switch circuits; remotely controlled door and time switch circuits; and theater-lighting circuits and switches. Throughout the book the policy has been to convey the information by pictures, and the quality of the more than 550 illustrations and diagrams used makes them represent a tremendous amount of work. Most of the matter relates to 110- to 220-volt two- and three-wire circuits and is set forth so as to comply with the National Electrical Code. The book has been prepared as a practical reference for all those who may be concerned with interior-lighting circuits, and for this class of reader it will have a wide field of usefulness.

Increased Production of Electricity in 1922

The electric public utility power plants have increased production in 1922. According to the Geological Survey over one third of the total amount of electricity produced in the United States was generated by water-power plants thereby conserving over 20,000,000 tons of coal in 1922. New York is the leading state in the production of electricity by water power but California ranks second with one-fifth of the total amount of electricity produced by water power in the United States to the credit of her hydro-electric plants.

There has been a remarkable increase in the efficiency in the utilization of fuel during the four years from 1919 to 1922. In 1919 the average consumption of coal required to generate kw.-hr. was 3.2 lb. in 1922 but 2.5 lb. was required, a decrease of 22 per cent, representing a saving of millions of tons of coal.

ANNUAL PRODUCTION OF ELECTRICITY BY PUBLIC-UTILITY POWER PLANTS IN THE UNITED STATES 1919-22

	Total		Water Power			Fuel Power		
Year	Kilowatt-Hours, Millions	Change From Previous Year (Per Cent)	Kilowatt-Hours, Millions	Per Cent of Total	Change From Previous Year (Per Cent)	Kilowatt-Hours, Millions	Per Cent of Total	Change From Previous Year (Per Cent)
1919	38,921	.....	14,606	37.5	.....	24,315	62.5	.....
1920	43,555	+11.9	16,150	37.1	+10.6	27,405	62.9	+12.7
1921	40,976	—5.9	14,971	36.5	—7.3	26,005	63.5	—5.1
1922	47,659	+16.3	17,206	36.1	+14.9	30,453	63.9	+17.1

ANNUAL CONSUMPTION OF FUEL IN THE PRODUCTION OF ELECTRICITY BY PUBLIC-UTILITY POWER PLANTS IN THE UNITED STATES 1919-22

	Coal		Fuel Oil		Gas	
Year	Short Tons	Change From Previous Year (Per Cent)	Barrels	Change From Previous Year (Per Cent)	M Cubic Feet	Change From Previous Year (Per Cent)
1919	35,100,000	.....	11,050,000	.....	21,406,000	.....
1920	37,124,000	+5.8	13,123,000	+18.8	24,702,000	+15.4
1921	31,585,000	—14.9	12,045,000	—8.2	23,722,000	—4.0
1922	34,179,000	+8.3	13,197,000	+9.6	27,172,000	+14.5

AVERAGE CONSUMPTION OF COAL PER KILOWATT-HOUR BY PUBLIC-UTILITY POWER PLANTS IN THE UNITED STATES 1919-22

		Consumption of Coal and its Equivalent† in Other Fuels		
Year	Output by the Use of Fuel* (Kilowatt-hours)	Net Tons	Pounds per Kilowatt-hour	Percentage of 1919 Rate
1919	24,176,000,000	38,880,000	3.2	100
1920	27,248,000,000	41,420,000	3.0	94
1921	25,863,000,000	35,240,000	2.7	84
1922	30,240,000,000	38,000,000	2.5	78

* Coal, oil, and gas. † One ton coal = 4 bbl. oil = 35,000 cu.ft. of gas (approximately.)

Society Affairs

The **Tennessee Subordinate** No. 1 of the National Association of Practical Refrigerating Engineers is making extensive preparations for the 14th annual convention which will be held in Memphis, Tenn., Dec. 12-15.

The **Brooklyn Engineers' Club** gave a dinner to commemorate the 25th year of its organization and also to honor the new president, Linford S. Stiles, on June 26, at Feltman's Wisteria Colonnade, Coney Island. Over 350 members were present.

The **Southern Local Sections** of the **A.S.M.E.** will hold a Regional Meeting at Chattanooga, Tenn., on Oct. 23-24. Birmingham, Atlanta, Knoxville and the Carolina sections have promised co-operation. The program will probably include three sessions—hydro-electric-power, management and welding. The professional division on power, management and machine-shop practice will assist in the preparation of the program for these sessions.

The **Society for Testing Materials** elected the following officers for the ensuing year at the recent meeting at Atlantic City: President, Guilliaem Aertsen, Bethlehem Steel Co., Chicago; vice-president, W. H Fulweiler, United Gas Improvement Co., Philadelphia; members of the executive committee, J. H. Chubb, Universal Portland Cement Co., Chicago; T. G. Delbridge, Atlanta Refining Co., Philadelphia; P. H. Walker, Bureau of Standards, Washington, D. C.; H. C. Scott, L. H. Scott & Co., Providence, R. I.

The **Pacific Coast Convention** of the **A.I.E.E.** will have on its program a symposium, by transmission engineers of the Great West, on Waterwheel Construction, Operation and Governing, etc. The following papers will be read: "General Consideration of the Subject," by John Harrisberg, Puget Sound Power & Light Co.; "Waterwheel Construction, Operation and Governing," by E. D. Searing, Portland Railway, Light & Power Co.; "A Study of Irregularity of Reaction in Francis Turbines," by R.

Wilkins, Pacific Gas & Electric Light Co.; "General Considerations of the Subject," by H. L. Doolittle, Southern California Edison Co.

Personal Mention

Charles H. Bigelow, formerly with the Millville Manufacturing Co., is now plant engineer for the Spicer Manufacturing Corp., South Plainfield, N. J.

Bruno V. Nordberg, president of the Nordberg Manufacturing Co., Milwaukee, Wis., has recently had the degree of Doctor of Engineering conferred upon him by the University of Michigan.

L. B. Breedlove has been employed by the Chicago Trust Co. as a consulting engineer in an advisory capacity with reference to loans on industrial and public utilities and with some general supervision of operation.

Dr. A. S. McAllister, engineer physicist, of the Bureau of Standards, who has during the last two years been liaison officer of the United States Bureau of Standards and the Federal Specification Board, assigned to the American Engineering Standards Committee at New York, has been recalled to Washington for special work by Secretary Hoover of the Department of Commerce.

Hon. Joseph E. Michaud, member of the Provincial Government without portfolio, has been appointed a member of the New Brunswick Electric Power Commission. The appointment was made at a meeting of the Cabinet, when the resignation of Hon. L. A. Dugal, of Edmundston, as a member of the commission was received and accepted. Mr. Michaud will take up his new duties immediately.

George T. Ladd, president of the Geo. T. Ladd Co., manufacturer of the Ladd water-tube boilers, Pittsburgh, Pa., has been appointed a member representing Pittsburgh section of a subcommittee of the A.S.M.E. on the storage of coal. This committee is a part of a large committee recently appointed by the Federated American Engineering Societies and was organized to determine the engineering, mechanical and economic factors involved in the storage of coal and the influence of those factors on storage at the mine by the various classes of consumers.

Business Notes

The **James Howden Co. of America, Inc.,** Wellsville, N. Y., has taken over the Ljungstrom air preheater patents and will make and sell these preheaters for unlimited marine use and for stationary use in the United States.

Templeton Brothers, Inc., have been incorporated under the laws of Massachusetts and are located at 127 Heath St., Boston, Mass. William R. Templeton is president, N. D. Jackson treasurer, and William P. Mower secretary. The company will manufacture return traps and specialize in traps for boiler feeding and pumping.

The **Connecticut Blower Corp.,** Hartford, Conn., has been incorporated under the laws of Delaware, with M. E. Keeney as president, C. H. Keeney treasurer and C. E. Keeney secretary. The International Blower Co. and the Hartford Sheet Metal Works have been taken over. The company expects to manufacture and install blowers, exhaust fans, and dust collecting exhaust and ventilating systems.

Coming Conventions

American Institute of Electrical Engineers, F. L. Hutchinson, 29 West 39th St., New York City. Pacific Coast Convention at Del Monte, Calif., Oct. 2-5.

American Institute of Mining and Metallurgical Engineers; F. F. Sharpless, 29 West 39th St., New York City. Annual meeting at Ontario, Quebec, Canada, Aug. 20-31.

American Society of Mechanical Engineers, Calvin W. Rice, 29 West 39th St., New York City. Annual meeting at New York City, Dec. 3-6.

Association of Iron & Steel Electrical Engineers; J. F. Kelly, 1007 Empire Bldg., Pittsburgh, Pa. Iron and Steel Exposition at Buffalo, N. Y., Sept. 24-28.

American Society of Refrigerating Engineers, William H. Ross, 35 Warren St., New York City. Nineteenth Annual Convention at New York City, Dec. 3-5.

International Union of Steam and Operating Engineers; Dave Evans, 6334, Yale Ave., Chicago, Ill. Annual convention at Detroit, Sept. 10-15.

National Association of Practical Refrigerating Engineers; Ed. H. Fox, 914-25 East Jackson Blvd., Chicago. Fourteenth Annual Convention at Memphis, Dec. 12-16.

National Association of Stationary Engineers; Fred W. Raven, 417 South Dearborn St., Chicago, Ill. Annual convention and exhibition at Buffalo, N. Y., Sept. 10-15. Annual conventions and exhibitions of the State Associations scheduled as follows: **Michigan** at Flint, July 18-20. E. C. Smith, 308 Vine St., Kalamazoo, Mich. **Pennsylvania,** at Buffalo, Sept. 9-10; J. N. Calvert, Crafton Sta., Pittsburgh, Pa. **New York,** at Buffalo, Sept. 9-10; W. T. Meinzer, Third St., near Warburton, Bayside, L. I., N. Y. **Minnesota,** at Duluth, Aug. 8-10; C. A. Nelson, 800 22d Ave. N. E., Minneapolis.

National Safety Council, W. H. Cameron, 168 North Michigan Ave., Chicago, Ill. Twelfth annual congress at the New Statler Hotel, Buffalo, N. Y., Oct. 1-5.

New England Association of Commercial Engineers; James F. Morgan, 53 Devonshire St., Boston, Mass. Power Show at Mechanics Bldg., Boston, Mass., Oct. 29-Nov. 3.

The New England Water Works Association; Frank J. Gifford, 715 Tremont Temple, Boston, Mass. Annual Convention at Burlington, Vermont, Sept. 18-21.

National Exposition of Power and Mechanical Engineering; Charles F. Roth, Room 1102, Grand Central Palace, New York City. Power Show, Dec. 3-8.

Society of Naval Architects and Marine Engineers, Daniel H. Cox, 29 West 39th St., New York City. Annual meeting at New York City, Nov. 8-9.

Universal Craftsman Council of Engineers; John F. Amos, P. O. Box 299, Rochester, N. Y. Convention at Rochester, N. Y., Aug. 7-11.

Trade Catalogs

Filters and Extractors—Elliott Co., Pittsburgh, Pa. Catalog R-1 describes Lagonda Grease Extractors by means of numerous illustrations, and discusses oil, grease and sediment in feed water.

Stoker — Combustion Engineering Corp., Broad St., New York City. Pamphlet describing type K stoker for operating boilers ranging up to 200 hp.; contains drawings as well as test data.

Deaërators—Elliott Co., Pittsburgh, Pa. Bulletin N-4—"Conquering Corrosion," tells how deaërated water protects pipe lines, economizers, boilers, etc. The illustrations show installations of deaërators and the text describes them.

Water Softener, Hot Process—Graver Corp., East Chicago, Ill. Booklet "'Zero' or One and One-Half. Which?" Contains descriptions of the two methods of water softening, the hot process and the zeolite process, the chemistry of water softening, the advantages of the two systems and tables of analysis of the water of Lake Michigan softened by the two processes.

Fuel Prices

BITUMINOUS COAL

The following table shows the trend of the spot steam market in various coals (mine run bases, f.o.b. mines):

Coal	Market Quoting	July 2, 1923	July 9, 1923
Pool 1,	New York	$3.50@3.75	$3.25@3.75
Smokeless,	Columbus	3.50@3.75	3.00@3.50
Clearfield,	Boston	2.00@2.75	2.00@2.50
Somerset,	Boston	2.25@3.00	2.25@2.75
Kanawha,	Columbus	1.75@2.00	1.75@2.00
Hocking,	Columbus	1.75@2.00	1.75@2.00
Pittsburgh No. 8	Cleveland	1.90@2.00	1.80@2.00
Franklin, Ill.	Chicago	2.75@3.25	2.75@3.25
Central, Ill.	Chicago	2.00@2.25	2.00@2.25
Ind. 4th Vein,	Chicago	2.50@2.75	2.50@2.75
West Ky.,	Louisville	1.65@1.85	1.50@1.85
S. E. Ky.,	Louisville	1.75@2.25	1.50@2.25
Big Seam,	Birmingham	1.85@2.25	1.85@2.25

FUEL OIL

New York—July 12, Port Arthur light oil, 22@25 deg. Baumé, 5⅜c. per gal.; 30@35 deg. 5¾c. per gal., f.o.b. Bayonne, N. J.

Chicago—June 29, 24@26 deg. Baumé, $1.97 per bbl.; 32@36 deg., $2.27 per bbl., tank cars.

St. Louis—July 3, tank-car lots, f.o.b. St. Louis: 24@26 deg., $1.75 per bbl.; 26@28 deg., $1.80 per bbl.; 28@30 deg., $1.85 per bbl.; 32@36 deg., gas oil, $2.15 per bbl.; 36@40 deg., distillate, $2.35@$2.40 per bbl.

Pittsburgh—June 28, f.o.b. local refinery, 30@34 deg., fuel oil, 4¼c. per gal.; 36@40 deg., fuel oil, 5¼c. per gal.; 34 deg., neutral, 8½c. per gal.

Dallas—July 7, f.o.b. local refinery, 26@30 deg., $1.40 per bbl.

Cincinnati—July 3, tank car lots f.o.b. local refinery, 26@30 deg. Baumé, 4¾c. per gal.; 30@32 deg., 5c. per gal.; 38@42 deg., distillate, 6¼c. per gal.

New Plant Construction

PROPOSED WORK

Ala., Mobile—The Office of United States Engineer, 352 Government St., is in the market for one gasoline engine, 4 cycle, 4 cylinder, 30 hp.

Ark., Hot Springs — C. G. Owens, c/o Sorey & Vahlberg, Archts., 233 Terminal Arcade Bldg., Oklahoma City, Okla., is having plans prepared for the construction of a 6 story, 75 x 93 ft. hotel, here. Estimated cost $250,000. Equipment detail not reported.

Ark., Little Rock—The Constr. Division, Quartermaster Corps, Wash., D. C., plans to build an addition to the United States Veterans Hospital, to contain 200 beds, here.

Calif., Los Angeles—The County Supervisors will receive bids until July 23 for furnishing and installing two sewage pumps with piping and incidental equipment for septic tank; one Imhoff tank with sump and sludge bed.

Calif., Los Angeles—The St. Vincent Hospital, 1151 Sunset Blvd., is having plans prepared for the construction of a group of hospital buildings with separate heating plant. Estimated cost $1,000,000. J. G. Austin, Baker-Detwiler Bldg., Los Angeles, Archt. Noted Feb. 27.

Calif., Montebello—The Montebello Irrigation Dist. received bids for furnishing and laying pipe, valves, etc.; steel tower, 25 ft. high, tank, 250,000 gal. capacity; construction of pumping plant from the Lacy Mfg. Co., 1000 North Main St., Los Angeles, $64,475; Baker Iron Wks., 912 North Broadway, Los Angeles, $68,051; Western Pipe & Steel Wks., 5717 Santa Fe Ave., $69,945. Bids for other sections of work were also received. Noted Feb. 13.

Calif., Monterey—O'Brien Bros., Inc., Archts., 315 Montgomery St., San Francisco, are receiving bids for the construction of a 3 and 4 story hotel to contain 200 rooms, here, for R. Jacks, c/o Archts. Estimated cost $250,000. Equipment detail not reported. Noted Apr. 10.

Calif., Sacramento—The Elks Club, c/o E. C. Hemmings and L. F. Starks, Associated Archts., Ochsner Bldg., is having plans prepared for the construction of a 6 story, 100 x 160 ft. store and lodge building on 11th and J Sts. Estimated cost $1,000,000. J. C. Petersen, Peoples Bank Bldg., Sacramento, Consult. Archt. Equipment detail not reported.

Calif., Sacramento — The Sacramento Athletic Club, c/o L. Starks, Archt., Ochsner Bldg., is having plans prepared for the construction of a 4 story club building. Estimated cost $600,000. Equipment detail not reported.

Calif., San Diego—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., is having plans prepared for light, power and telephone systems at the Destroyer Base, here.

Calif., San Jose—The County of Santa Clara received bids for furnishing and installing a refrigerating and ice making plant at the county hospital from the Vulcan Iron Wks., Francisco and Kearny Sts., San Francisco, $4,787; York-California Constr. Co., 832 Folsom St., San Francisco, $5,575; Automatic Refrigerating Co., 338 Brannan St., San Francisco, $5,975; Cyclops Iron Wks., 837 Folsom St., San Francisco, $6,149. Noted June 12.

Calif., Visalia — The California Hot Springs, c/o J. Mitchell, plans to build a hydro-electric generating plant to supply electricity for resort.

Colo., Denver—J. A. Wetmore, Acting Supervising Archt., Wash., D. C., will receive bids until Aug. 2 for the complete installation of one full magnet electric freight elevator, for the United States Mint, here.

D. C., Wash.—A. L. Flint, Genl. Purch. Officer of the Panama Canal, will receive bids until July 20 for one boiler, electro steam, 2,200 volt, 3 phase, 25 cycle, 1,000 kw. capacity, 3,000 lb. of steam per hour for operation at 225 lb. gauge pressure.

Ill., Chicago—W. F. Gleck & Co., 1848 North Lamon St., are in the market for a 25 hp. motor for machine shop.

Ill., Chicago—F. A. Siebold, Jr., c/o B. F. Steif & Co., Archts., 64 West Randolph St., is having plans prepared for the construction of a 16 story, 100 x 150 ft. apartment house, including steam heating system, on Sheridan and Brompton Sts. Estimated cost $7,000,000.

Ill., Chicago—The Washington Blvd. Hospital, Washington and Campbell Sts., is having plans prepared for the construction of a 5 story addition to its hospital, including steam heating system. Estimated cost $200,000. Berlin, Swem & Randall, 17 South La Salle St., Chicago, Archts.

Ill., East St. Louis—The Stormcote Roofing Corp., 31st and St. Clair Sts., is in the market for one 50 hp. variable speed engine.

Ill., Springfield—The city defeated $350,000 bond issue for the construction of waterworks improvements, including high and low service pumps, basin filters, softening plant, etc. Burns & McDonnell, 401 Interstate Bldg., Kansas City, Mo., Engrs Noted June 26.

Ind., Elkhart — J. A. Wetmore, Acting Supervising Archt., Treasury Dept., Wash., D. C., will receive bids until July 23 for furnishing and installing one horizontal smokeless fire box boiler arranged for portable setting, at the United States Post Office, here.

Ky., Danville—The Dix River Power Co., a subsidiary of the Middle West Utilities Co., 72 West Adams St., Chicago, is having plans prepared for the construction of a dam, 250 ft. high, also a 30,000 kw. hydro-electric plant on the Dix River, two miles above its confluence with the Kentucky River, near here. Cost between $2,000,000 and $3,000,000. L. E. Harza, c/o owner, Engr.

Minn., Willmar—The city, H. Gunderson, Clk., will receive bids until July 23 for waterworks improvements, 500,000 gal. steel or concrete reservoir and pumping equipment. Separate bids will be accepted. Estimated cost $35,000. Cory & LeCocq, Aberdeen, S. D., Engrs. Noted May 1.

Mo., Cameron — The city defeated the $75,000 bond issue for the construction of waterworks and lighting system. A new election will soon be called. E. E. Harper, 3031 Park Ave., Kansas City, Engr. Noted June 19.

N. J., Newark—The Goerke Co., Halsey and Broad Sts., will soon receive bids for the construction of an addition to its department store, consisting of three 8 story units. Estimated cost $5,000,000. W. E. Lehman & Co., 738 Broad St., Newark, Engrs. and Archts. Equipment detail not reported.

N. J., Pennington—The city council rejected bids for extension to waterworks system, including electrically operated pumping station. Bids will be readvertised. Remington & Vosbury, 601 Market St., Camden, Engrs. Noted June 19.

N. Y., Brooklyn—The Bikur-Cholim Hospital, Lafayette and Summer Aves., is having plans prepared for the construction of a 7 story hospital building. Estimated cost $1,000,000. A. Weiser, 9 West 48th St., New York, Archt. Equipment detail not reported.

N. Y., East Creek — The Adirondack Power & Light Corp., 511 State St., Schenectady, plans hydro-electric power development, including dam, power house, penstock and generating equipment, here. Estimated cost $1,500,000.

N. Y., Hornell—The Hornell Electric Co., 30 Canastota St., is in the market for power plant machinery and equipment for its plants at Danville and Hornellsville. Noted June 26.

N. Y., Jamestown—C. A. Nelson, Route 75, is in the market for one large stage and size air compressor with electric motor, also pumps, etc., for gasoline distributing station.

N. Y., New York—The city, Municipal Bldg., will soon receive bids for the construction of a women's court house and detention rooms at 135 West 30th St. Estimated cost $600,000. Private plans. Equipment detail not reported.

N. Y., North Albany (Albany P. O.)—The Adirondack Power & Light Corp., 511 State St., Schenectady, plans to build a substation, here. Estimated cost $40,000.

N. Y., Ogdensburg—B. A. Evans is in the market for an air compressor and tank, also two electrically operated gas pumps for proposed machine shop, repair and service station at Gouverneur.

N. C., Kinston—The Caswell Training School, C. B. McNairy, Supt., will receive bids until July 31 for mechanical equipment, including boilers, engines, generators and switchboard, also for the construction of laundry building. H. A. Underwood, 916 Commercial Bank Bldg., Raleigh, Engr. Noted May 29.

N. C., Raleigh—The City Comrs. will receive bids until Aug. 1 for equipment to increase pumping capacity of the Raleigh water system from 3,500,000 g.p.d. to 5,000,000 g.p.d., including concrete basin; four filter tubes, 500,000 gal. capacity, each; enlargement of present facilities, etc. C. C. Page, Engr. Estimated cost $350,000.

N. D., Fargo—The city will receive bids until Aug. 1 for one 750 gal. and one 1,000 gal. capacity triple comb pumper. R. T. Jacobson, City Engr.

Ohio, Akron—The Northern Ohio Traction & Light Co., Terminal Bldg., is having plans prepared for the construction of a 3 story, 47 x 65 ft. power substation at 461 Water St. Estimated cost $135,000. J. Eckrode, Terminal Bldg., Engr. Noted May 22.

Ohio, Botzum—The city of Akron is having plans prepared for the construction of a sewage disposal plant, here. Estimated cost $1,000,000. Metcalf & Eddy Eng. Co., 14 Beacon St., Boston, Engrs.

O., Cleveland—The County Comrs., c/o R. J. Lander, Surveyor, Cuyahoga County Court House, is in the market for an ice machine for county morgue.

Ohio, Columbus—The Bd. of Trustees, C. E. Steele, Secy., will receive bids until July 25 for the construction of a connection between the Olentangy River and condensers in boiler house at the Ohio State University. Estimated cost $30,000. J. N. Bradford, c/o owner, Engr.

Okla., Slick—The city is having plans and surveys made for the construction of wells, water distribution system, tank, tower, deep well pump, etc. Estimated cost $40,000. Gant & Baker, 1st Natl. Bank, Oklahoma City, Engrs.

Okla., Tulsa — The City Water Comn., A. J. Rudd, Chn., City Hall, will receive bids until July 30 for furnishing pumps and boilers for the Mohawk Pumping Sta. of the Spavinaw Water Supply Project on two alternate plans: (A) two 12,000 gal. steam turbine driven centrifugal pumping engines; two 300 hp. water tube boilers; (B) two 12,000 gal. motor driven centrifugal pumping engines. J. D. Trammell and W. R. Holway, 508 Wright Bldg., Tulsa, Engrs. D. H. Maury, 1445 Monadnock Block, Chicago, Consult. Engr.

Pa., Oil City—The Citizens Light & Power Co., North Seneca St., plans to build a distributing station or a substation. Cost will exceed $40,000.

Pa., Pittsburgh—T. Pringle, Archt., Renshaw Bldg., will receive bids until July 20 for the construction of an 8 story, 80 x 120 ft. welfare building on 2nd, 3rd and Cherry Sts. for the Salvation Army, 324 Diamond St. Estimated cost $500,000. Equipment detail not reported. Noted Nov. 7, 1922.

Pa., Salford (Rudy P. O.)—The Salford Light & Power Co. plans to build a light and power plant. Estimated cost $25,000. The owner is in the market for machinery and equipment.

Tex., Beaumont—Jefferson County, B. B. Johnson, Judge, will receive bids until Aug. 7 for the construction of a bridge over the Neches River, including a draw span motor driven with gasoline auxiliary. A. C. Love, County Engr. Noted May 22.

Tex., Dallas — The North Texas Trust Co., c/o C. S. Mitchell, 708 Mercantile Bank Bldg., is having plans prepared for developing Kessler Park, adjoining Kessler Sq., including waterworks, sewers, electric lighting system, etc. Estimated cost $200,000. Koch & Fowler, Central Bank Bldg., Engrs.

S. C., Columbia—The Mayor and City Council will receive bids until Aug. 7 for pumping equipment, two units each, consisting of one horizontal split case single stage centrifugal pump, capacity 8,325 g.p.m., direct connected with electric motor. W. S. Tomlinson, Engr.

Va., Blackstone—The city is in the market for pumping machinery and power equipment for waterworks.

Wis., Beloit—The Beloit Municipal Hospital Com., T. B. Woolsey, Chn., Hook Bros., Bldg., plans to build a 4 or 6 story hospital. Estimated cost $250,000. Engineer or architect not announced.

Wis., Fort Atkinson—The city, W. D. Leonard, Clk., received bids for the construction of a pumping station and reservoir, 60 ft. diameter, 15 ft. deep, from T. S. Willis, 330 Hayes Block, Janesville, reservoir, $8,214, pumping station $8,696; W. H. Deason, 357 Washington Bldg., Madison, reservoir, $10,031, pumping station, $7,790. Noted June 19.

Wis., Green Bay—The Bd. Educ., I. H. McIntire, Supt., is receiving bids for a steam heating plant, including boilers, radiation and heat regulation, for Elmore school. Private plans.

Wis., La Crosse—The La Crosse Lutheran Hospital, 1910 South Front St., received bids for the construction of a 3 story, 42 x 100 ft. nurses' home, also for remodeling boiler house and power plant from T. Malzahn, Majestic Bldg., La Crosse, $63,521; P. Nelson & Son, Newburg Bldg., La Crosse, $66,856; Madsen & Petersen, 646 Builders' Exch., Minneapolis, Minn., $73,786. Noted June 26.

Wis., Manitowoc—E. Brielmaier & Sons Co., Archts., 432 Broadway, Milwaukee, are receiving bids for the construction of a 4 story, 50 x 250 ft. addition to hospital for the Holy Family Hospital, c/o Franciscan Sisters, here. Estimated cost $300,000. Equipment detail not reported. Noted Apr. 10.

Wis., Manitowoc—The city, A. H. Zander, Clk., is receiving bids for the construction of a 1 story, 55 x 65 ft. addition to municipal water and light plant. F. Alter, City Hall, Engr. Noted May 22.

Wis., Sheboygan—E. A. Juul, Engr., Security Bldg., will receive bids for a steam heating plant and boilers for temple building. Owner's name withheld.

Wis., Thorp—The city, c/o H. Holzhausen, is receiving bids for the construction of a concrete tank, 2 compartment, 14 x 14 ft.; 12 x 30 ft. sludge bed, 3 ft. deep; vit. sewer pipe; 4½ x 4½ ft. air cooled compressor; two air lift pumps and piping. Estimated cost $25,000. W. G. Kirchoffer, Dean Pldg., Madison, Engr. Noted June 26.

Ont., Cooksville—The City Council, G. M. Harris, Chn. Com., plans the installation of an electric lighting and power distribution system. Estimated cost $30,000.

Ont., Ottawa—The Dept. of Public Wks., R. C. Desrochers, Purch. Agt., will receive bids until July 19 for furnishing and installing a down draft smokeless boiler and other equipment at London; also in the market for boilers and other equipment for Ste. Anne's Military Hospital, Ste. Anne de Bellevue, Que.

Ont., Ottawa—The Dept. of Public Wks., R. C. Desrochers, Secy., will receive bids until July 27 for additional boiler and hot water heating plant at Maple Creek, Sask.

Ont., Sarnia — The Imperial Oil Co., C. Stillman, Mgr., is in the market for oil tanks and pumping equipment, to replace that which was destroyed by fire and explosion. Estimated cost $60,000.

Ont., Tamworth—A. B. Carscallen & Co. (feed mill and electric light plant) are in the market for a belt driven d.c. 125 volt generator, switchboard with equipment, one water wheel, shafts, etc.

Ont., Toronto—The city, C. A. Maguire, Mayor, City Hall, will receive bids until July 24 for furnishing and erecting two 2,880,000 Imperial gallon centrifugal sewage pumps, direct connected to electric motors. Estimated cost $30,000. R. C. Harris, Engr.

Ont., Toronto—The Mahaffy Iron Wks., 4 Trafalgar Ave., plans to build a factory on Kendall Ave. Estimated cost $50,000. The owner is in the market for motors, equipment, etc.

Ont., Walkerton—The City Council plans to build a stand pipe and pump house, install gasoline operated pumps and repair reservoir. Estimated cost $35,000. F. B. James, Walkerton, Engr. A bylaw will be submitted.

CONTRACTS AWARDED

Calif., Merced—The Merced Irrigation Dist. awarded the contract for furnishing thirty-five deep well turbine pumps to the Byron-Jackson Iron Wks., Sharon Bldg., San Francisco, $12,915; thirty-five induction type electric motors to the General Electric Co., Rialto Bldg., San Francisco, $16,700.

Calif., Oakland—M. F. Smith, 1001 Excelsior Ave., will build by day labor a 6 story store and hotel building on Oak and 12th Sts. Estimated cost $250,000. Equipment detail not reported. Noted June 26.

Calif., San Diego—The Balboa Theatre Building Co. awarded the contract for the construction of a theater and office building to the Wurster Constr. Co., 2136 Arctic St., San Diego. Estimated cost $645,000. Equipment detail not reported.

Fla., Stark—The city awarded the contract for two complete engine units and one fuel tank to Fairbanks, Morse & Co., 900 South Wabash Ave., Chicago; booster pump and well pump to the Worthington Pump & Mchy. Co., 115 Broadway, New York; well to the Southard Constr. Co.; meters and transformers to the Holt Electric Co., 379 South Pierce St., Milwaukee, Wis.; one constant transformer and street pole brackets to the Western Electric Co., 463 West St., New York. Noted June 5.

Ill., Chicago—W. H. Wilson, 845 Euclid Ave., representing owner, awarded the contract for the construction of a 16 story furniture exhibition, office and sales building, including steam heating system, at 664 Lake Shore Dr. to the Wells Bros. Constr. Co., 53 West Jackson St., Chicago. Estimated cost $8,000,000.

Mass., Boston—The Fensgate Realty Trust, 85 Devonshire St., awarded the contract for the construction of an 8 story apartment house at 536 Beacon St. to the F. J. Van Elten Co., 80 Boyleston St., Boston. Estimated cost $750,000. Equipment detail not reported.

Minn., Hutchinson — The city, J. Mikulecky, Clk., awarded the contract for one 125,000 gal. steel tank on 100 ft. tower to the Minneapolis Steel & Mchy. Co., 2854 Minnehaha Ave., Minneapolis, $13,100; one 300 g.p.m. centrifugal service pump and two 500 g.p.m. centrifugal booster pumps to the Worthington Pump & Mchy. Corp., 1017 Commerce Bldg., St. Paul, $4,446; 16 in. well to the McCarthy Well Co., Wabash and Eustis Sts., St. Paul, $2,160. Noted June 26.

Minn., St. Cloud—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., awarded the contract for the construction of hospital buildings for the United States Veterans' Bureau, here, to the Carter-Halls-Aldinger Co., Ltd., 706 1st Ave., Minneapolis. Estimated cost $519,656. Noted June 5.

Mo., Jefferson City—Lincoln University, c/o Curators, New York Life Bldg., Kansas City, awarded the contract for the construction of a 1 story, 36 x 40 x 51 ft. power plant, including boiler house and coal room, here, to the G. Griffith Constr. Co., Odd Fellows Bldg., St. Louis. Estimated cost $26,000. Bids for tunnels, conduits, boiler, smokestack, pumps, water heaters, generator, vacuum pumps, pipe lines, also dismantling and erecting present boilers will be awarded about July 16. Noted June 26.

Mo., St. Louis—M. Loew, 1540 Broadway, New York, awarded the general contract for the construction of a 3 story, 125 x 150 ft. theater and store building on Washington St., here, to the Ben Hur Erection Co., 4006 Natural Bridge St., St. Louis; structural steel to the Mississippi Valley Structural Steel Co., Arcade Bldg., St. Louis. Estimated cost $1,000,000. T. W. Lamb, Archt., 644 8th Ave., New York, will supervise sub-contracts. Noted May 22.

N. Y., Buffalo—The Westbrook Corp., 574 Main St., awarded the contract for the construction of a 10 story, 100 x 200 ft. apartment house on Delaware Ave. to D. P. Robinson & Co., Grand Central Palace, New York. Cost will exceed $600,000. Equipment detail not reported.

N. Y., Glens Falls—The Moreau Mfg. Co., M. Hoopes, Pres., awarded the contract for hydro-electric development, including the construction of a dam and power house at Sherman Island, here, to the Parklap Constr. Co., Glens Falls. Estimated cost $1,000,000.

N. Y., Heuvelton—The St. Lawrence Transmission Co., Potsdam, awarded the contract for the construction of a power house and concrete dam on the Oswegatchie River, here, to the G. W. Thompson Co., Gurney Bldg., Syracuse. Estimated cost $50,000.

N. Y., New York—The Dept. of Parks, Municipal Bldg., awarded the contract for the construction of pump house, pump pit and septic tank in Pelham Bay Park to the Sloane-Dickinson Corp., 136 Liberty St., New York. Estimated cost $28,550.

N. C., Cullowhee—The Bd. of Directors of the Cullowhee Normal and Industrial School, awarded the contract for the construction of power house and laundry building, to Hester & McElwee, Raleigh. Estimated cost $38,964. Noted May 22.

N. C., Greenville—H. A. Underwood, Engr., Commercial Bank Bldg., Raleigh, awarded the contract for the construction of buildings for the East Carolina Teachers College, here, to the J. E. Beaman Constr. Co., Commercial Bank Bldg., Raleigh. Estimated cost $1,025,000. Equipment detail not reported. Noted Apr. 3.

N. C., Sanatorium—The state, Raleigh, awarded the contract for the construction of power plant, piping apparatus, water pumping equipment and heating system in colored physicians' residence at the North Carolina Sanatorium, here, to the Dermott Heating Co., Durham. Estimated cost $33,150.

Ohio, Cincinnati — The Bd. Educ., 511 West Court St., awarded the contract for heating and ventilating in Hughes High School to the Williamson Heater Co., 335 West 5th St., Cincinnati, $36,190; in Hartwell Public School to the Sodemann Heat & Power Co., 2306 Morgan St., St. Louis, Mo., $43,447. Noted July 10.

Okla., Oklahoma City — The University Hospital, 800 East 13th St., awarded the contract for the construction of a 2 story power house to the Kreipke Schafer Constr. Co., 615 Hersk St. Estimated cost $50,000.

Okla., Sayre—The city awarded the contract for three wells; three motor driven triplex pump units, capacity 100 g.p.m.; pipe lines, well houses, etc., to the Ajax Constr. Co., 1824 West Main St., Oklahoma City. Estimated cost $30,887. Noted June 12.

Pa., Phila. — The General Electric Co., Witherspoon Bldg., awarded the contract for the construction for the first unit of six unit plant on a 20 acre tract on 56th St. and Elmwood Ave. to the White Constr. Co., 95 Madison Ave., New York.

S. D., Esmond—The city, C. B. Gardner, Clk., awarded the contract for distribution system, pump and one 20 hp. Fairbanks-Morse oil engine to Bruce-Bickelhaupt, Yankton, $8,384; tower and tank to the Pittsburgh-Des Moines Steel Co., 10th and Tuttle Sts., Des Moines, Ia., $5,450; pump house and reservoir, bids rejected, and city will build. Noted June 12.

Tenn., Nashville—The Scottish Rite Masons awarded the contract for the construction of a temple on 7th and Broad Sts. to the Hugger Bros. Constr. Co., Bell Bldg., Montgomery, Ala. Estimated cost $600,000. Equipment detail not reported. Noted Aug 22, 1922.

Tex., Port Arthur—The Eastern Texas Electric Co. awarded the contract for the installation of a 55,000 bbl. fuel oil tank and additional dockage facilities; also for construction of 3 story switchboard bay and installation of switchboard for Houston Ave. power station to Stone & Webster, Inc., 147 Milk St., Boston, Mass. Estimated cost of latter $135,000.

Va., Yorktown—The Bureau of Yards & Docks, Navy Dept., Wash., D. C., awarded the contract for power plant equipment at the Navy Mine Depot, here, to the Noland-Clifford Co., 322 28th St., Newport News, Va. Estimated cost $7,020. Noted July 10.

Wis., Little Chute—The village awarded the contract for the construction of pumping station and reservoir to the Appleton Constr. Co., Odd Fellows Bldg., Appleton, $9,900; 100,000 gal. steel tank, 100 ft. steel tower and foundation to the Pittsburgh-Des Moines Steel Co., 10th and Tuttle Sts., Des Moines, Ia., $10,000; drilling deep well to J. J. Faust & Son, Kaukauna. Bids were rejected on excavation, laying water mains and back filling. New bids will soon be received. Noted May 22.

Wis., Milwaukee — The city, Dept. of Public Wks., awarded the contract for the construction of a gate house and distribution system at Riverside pumping station to P. Riesen's Sons, 1018 Humboldt Ave., Milwaukee. Estimated cost $64,777. Noted July 10.

Wis., Milwaukee—The Sinclair Refining Co., 425 East Water St., will build by day labor a service and filling station, consisting of a 40 x 60 ft. main building and a 20 x 20 ft. pump house. Estimated cost $40,000. The owner is in the market for a 15,000 gal. oil storage tank and pumps.

Wis., Wautoma—Waushara County, c/o W. H. Benar, Chn., Court House, awarded the contract for the construction of a 1 story, 50 x 90 ft. central steam heating plant, to the Heating & Power Appliance Co., 200 Pleasant St., Milwaukee.

Ont., Hespeler—The Hespeler Woodworking Co. awarded the contract for the construction of a 2 story factory to W. Johnstone, Hespeler. Estimated cost $50,000 The owner is in the market for electric motor, etc.